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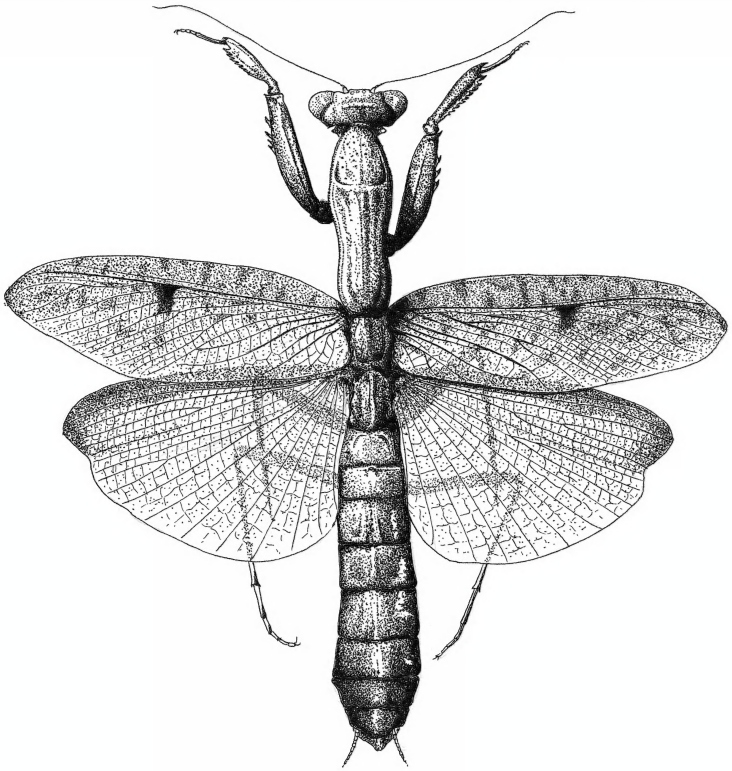

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DRAGONFLIES AND DAMSELFLIES (ODONATA) OF THE GRANITE BELT REGION, SOUTH-EASTERN QUEENSLAND, AUSTRALIA

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Abstract

Records of species of dragonflies and damselflies were collated from the Granite Belt region (more or less equivalent to the IBRA subregion of the Stanthorpe Plateau) in south-eastern Queensland. The Granite Belt is the most northerly extent of the New England Tablelands bioregion and is an elevated region (mostly above 800 m) characterised by adamellite domes and tors. Records of odonate species were collated from our own observations, photographs and collecting activities, specimens in the Queensland Museum, and specimens from other Australian museum collections and observational records from the Atlas of Living Australia. To date, a total of 58 species of Odonata have been recorded from the Granite Belt, 19 species of damselflies from seven families and 39 species of dragonflies from six families. The odonate fauna of the Granite Belt has strong southern affinities with almost all of the region's species occurring in the southern half of the continent. In terms of their distributions in Queensland, a little over half the species recorded from the Granite Belt are widespread extending north into the tropics. Most of the remaining species are restricted to south-eastern Queensland with 13 species potentially restricted within Queensland to the Granite Belt which is the northernmost extent of their national ranges. Some of these restricted species are associated with riverine habitats but more are associated with swamps and wet heaths in the south-eastern parts of Girraween National Park. The long-term persistence of these species in Queensland is at risk due to rising temperatures, more severe and prolonged droughts and more severe and frequent fires due to climate change.

Key words: Anisoptera, Zygoptera, New England Tablelands, Stanthorpe Plateau, Girraween National Park

Introduction

The Granite Belt of south-eastern Queensland lies on a stepped, elevated plateau varying in elevation from 450 to 1200 m above sea level (asl) with much of the region above 800 m asl. It derives its name from the region's prominent adamellite tors and domes. The Granite Belt is the most northerly extent of the nationally recognised New England Tablelands (NET) bioregion (IBRA version 7; DEE 2019; Young 1999) and largely corresponds to the Stanthorpe Plateau subregion named for the area's largest town of Stanthorpe. The biogeographic and

conservation significance of the Granite Belt has long been appreciated. Many species of plants and animals with temperate distributions reach their northern range limits in the Granite Belt. These include species that are widespread in southern Australia as well as species restricted to the New England Tablelands bioregion (Young 1999). In addition, the Granite Belt has a number of regionally endemic plant species. Thus, in terms of their distributions in Queensland, many of these species are restricted to the Granite Belt, increasing the conservation significance of the region at the state level. There is a surprisingly large number of dragonfly and damselfly species that follow this latter distributional pattern, i.e. in Queensland they only occur within the Granite Belt. Despite the significance of the Granite Belt's odonate fauna, however, there has been no previous attempt to document the species found in the region. Here we collate records of species of dragonflies and damselflies from Queensland's Granite Belt, based on our own collecting activities, photographs and observations, and specimens in entomological collections and observations by others when accompanied by identifiable photographs.

Methods

Study Area

Our definition of the Granite Belt region largely equates to the Stanthorpe Plateau subregion of the New England Tablelands (NET) IBRA bioregion (DEE 2019), but also includes part of the Tenterfield IBRA subregion that falls within Queensland (Fig. 1). The study area abuts the border of Queensland and New South Wales from approximately 151°36'E in the west to 152°08'E in the east. It includes Broadwater, Passchendaele and Poziers State Forests (SF), Girraween National Park (NP) and the southern part of Sundown NP (Fig. 1). The rest of Sundown NP lies within the 'traprock country' of the Nandewar IBRA bioregion and so we have not included records from that part of the park. Stanthorpe is the largest town in the Granite Belt which encompasses other towns such as Amiens, Applethorpe, Ballandean, Cherry Gully, Fletcher, Glen Aplin, Severnlea, The Summit, Thulimbah and Wallangarra (Fig. 1).

The Granite Belt is Queensland's coldest region, due in part to its elevation, and has a cool, sub-humid to temperate climate. Winters are cold with mean daily minimum and maximum temperatures of 3° C and 15° C respectively and summer temperatures rarely exceeding 33°C. Long-term mean annual rainfall for the Stanthorpe Plateau is 798.9 mm (DES 2019) but varies across the region. In Girraween NP the park headquarters on the drier western side of the park receives an average 850 mm annual rainfall compared to 766 mm in Stanthorpe, and 1076 mm on Mt Sugarloaf, north east of Girraween (records are not available from the wetter south-eastern part of the park) (McDonald et al. 1995).

In terms of habitat for odonates, riverine habitats dominate the region, accounting for more than 80% of aquatic ecosystems in the Stanthorpe Plateau (DES 2019). Notable creeks and rivers in the region include the Severn River, The Broadwater, and Accommodation, Bald Rock, Cannon, Quart Pot and Spring Creeks. Artificial,

Fig. 1. Map of the Granite Belt which largely corresponds to the grey-shaded area. Most of the grey area corresponds to the IBRA subregion of the Stanthorpe Plateau except for the 'wedge' abutting the New South Wales Border which is the part of the IBRA Tenterfield subregion that extends into Queensland. National Parks and State Forests are shaded with green. The darker green area of Sundown NP is the part of the park included within the Stanthorpe Plateau subregion.

highly modified wetlands such as dams and impoundments account for 15% of aquatic habitats in the region (DES 2019). Storm King Dam (28°42'S 151°59'E), Stanthorpe's water supply, is the largest artificial water body in the region. Finally, non-floodplain swamps contribute 2.5% of the region's aquatic ecosystems (DES 2019): significant upland sedgeland and wet heath swamp communities in the headwaters of streams, particularly in Girraween NP (e.g. Dingo Swamp in the head of Racecourse Creek in the vicinity of South Bald Rock).

Compilation of Odonata records

Most odonate records from the Granite Belt are from Girraween NP where there has been considerable survey effort. Deniss Reeves and Harry Hines (HBH) made substantial collections of Odonata in the park in January 2000 and January 2001 and HBH collected additional specimens while conducting frog surveys in the park between 1999 and 2006 (all specimens in the Queensland Museum (QM)).

Chris Burwell (CJB) and Rod Hobson (RGH), accompanied by various other collectors, made three visits to Girraween NP specifically to survey Odonata; February 2014, January 2015 and January 2018 (specimens in QM). Narelle Power (NPP) and Damian White (DW) visited Girraween NP on several occasions between 2014 and 2019 specifically photographing dragonflies and damselflies. In addition, Michael Jefferies (MGJ) was a long-term resident of Stanthorpe and photographed a number of species of Odonata in Girraween NP and the wider Granite Belt region between December 2006 and March 2013.

In addition to our own collecting and photographic activities, Odonata records from the Granite Belt were obtained from a number of other sources. Additional specimen records in the collections of the Queensland Museum (QM) were collated by CJB and Karin Koch, and specimen records or observational records of species where accompanied by identifiable photographs, from the region were also sourced from the Atlas of Living Australia (ALA, https://www.ala.org.au last accessed 26 September 2019).

The family-level taxonomy used in this paper largely follows the world systematic consensus of Odonata presented by Dijkstra et al. (2013) except that all megapodagrionids are placed in the Argiolestidae as established by Kalkman and Theischinger (2013). A number of genera within the Libelluloidea were not assigned to a particular family by Dijkstra et al. (2013). Two genera with species in the Granite Belt, *Austrocordulia* Tillyard and *Cordulephya* Selys, were not assigned to any particular family by Dijkstra et al. (2013) and we treat them here as Libelluloidea incertae sedis.

Results

Based on our own surveys (specimen-based and photographic), specimens in insect collections (Queensland Museum and others sourced from the ALA), and observational records with photographs in ALA, a total of 58 species of dragonflies and damselflies representing 13 families are known from the Granite Belt region (Table 1). Dragonflies, with 39 species, greatly outnumber damselflies with 19 species, about the same ratio as the Australian fauna overall. A brief synopsis of each family is presented below followed by a discussion of the broader affinities of the odonate fauna of the Granite Belt region. Notes on the distributions of individual species presented below are largely based on the distribution maps presented in Theischinger and Endersby (2009) supplemented by data from our own collecting activities in Queensland.

Suborder Zygoptera (Damselflies)

Family Synlestidae

Synlestids are represented by two species in the Granite Belt, *Episynlestes albicauda* (Tillyard) (Southern Whitetip) and *Synlestes weyersii* Selys (Bronze Needle). The former is represented by only three specimens from Girraween NP; one from the headwaters of Accommodation Creek and two from Beehive Gully,

Table 1. Dragonfly and damselfly species recorded from the Granite Belt. Species have been classified according to their distribution within Queensland largely based on the distribution maps presented in Theischinger and Endersby 2009: widespread - either extending north beyond the central Queensland coast or well inland; southern Queensland—occurring north beyond south-east Queensland but south of the central Queensland coast; SE Qld—largely confined to south-eastern Queensland (as far north as the Sunshine Coast Hinterland) but some species with disjunct populations at Carnarvon Gorge and/or the Clarke Range of central coastal Queensland; Granite Belt—restricted to the Granite Belt. 'P' indicates the species has been recorded from the Granite Belt only on the basis of a photograph/s, 'O' indicates the species has only been observed within the Granite Belt, and not confirmed by photographs or the collection of specimens. All other species are represented by specimens collected within the Granite Belt. Both *Austrolestes icteromelas* in the broad sense and the particular subspecies occurring in the Granite Belt, *A. i. icteromelas*, have been included.

Scientific name	**Common Name**	**Qld Distribution**
Suborder Zygoptera (damselflies)		
Family Synlestidae		
Episynlestes albicauda	Southern Whitetip	southern Qld
Synlestes weyersii	Bronze Needle	SE Qld, Carnarvon Gorge
Family Lestidae		
Austrolestes analis	Slender Ringtail	Granite Belt
Austrolestes cingulatus	Metallic Ringtail	Granite Belt
Austrolestes leda	Wandering Ringtail	widespread
Austrolestes psyche	Cup Ringtail	SE Qld
Family Lestoideidae		
Diphlebia coerulescens	Sapphire Rockmaster	SE Qld, Clarke Ra., Kroombit Tops
Diphlebia nymphoides	Arrowhead Rockmaster	SE Qld, Carnarvon Gorge
Family Argiolestidae		
Austroargiolestes amabilis (O)	Flame Flatwing	SE Qld
Austroargiolestes icteromelas	Common Flatwing	widespread
(*A. i. icteromelas*)		SE Qld only
Griseargiolestes eboracus	Grey-chested Flatwing	Granite Belt
Family Isostictidae		
Rhadinosticta simplex	Powdered Wiretail	widespread
Family Platycnemididae		
Nososticta solida	Orange Threadtail	widespread

Family Coenagrionidae		
Austroagrion watsoni	Eastern Billabongfly	widespread
Caliagrion billinghursti	Large Riverdamsel	Granite Belt
Ischnura aurora	Aurora Bluetail	widespread
Ischnura heterosticta	Common Bluetail	widespread
Pseudagrion aureofrons	Gold-fronted Riverdamsel	widespread
Xanthagrion erythroneurum	Red and Blue Damsel	widespread
Suborder Anisoptera (dragonflies)		
Family Aeshnidae		
Adversaeschna brevistyla	Blue-spotted Hawker	widespread
Anax papuensis	Australian Emperor	widespread
Austroaeschna parvistigma (P)	Swamp Darner	Granite Belt
Austroaeschna pulchra	Forest Darner	SE Qld
Austroaeschna unicornis	Unicorn Darner	SE Qld
Austrogynacantha heterogena	Australian Duskhawker	widespread
Austrophlebia costalis	Southern Giant Darner	SE Qld, Clarke Ra.
Telephlebia godeffroyi	Eastern Evening Darner	Granite Belt
Family Petaluridae		
Petalura gigantea (O)	South-eastern Petaltail	Granite Belt
Family Gomphidae		
Austroepigomphus praeruptus	Twinspot Hunter	widespread
Austrogomphus amphiclitus	Pale Hunter	widespread
Austrogomphus australis	Inland Hunter	widespread
Austrogomphus cornutus	Unicorn Hunter	widespread
Austrogomphus guerini	Yellow-striped Hunter	SE Qld
Austrogomphus ochraceus	Jade Hunter	SE Qld
Hemigomphus gouldi	Southern Vicetail	SE Qld
Hemigomphus heteroclytus	Stout Vicetail	widespread
Family Synthemistidae		
Archaeosynthemis orientalis	Eastern Brown Tigertail	Granite Belt
Choristhemis flavoterminata	Yellow-tipped Tigertail	widespread
Eusynthemis aurolineata	Variable Tigertail	SE Qld
Eusynthemis nigra	Black Tigertail	widespread
Eusynthemis virgula	Golden Tigertail	Granite Belt

Family Synthemistidae (Cont.)		
Parasynthemis regina	Royal Tigertail	southern Qld
Synthemis eustalacta	Swamp Tigertail	Granite Belt
Family Corduliidae		
Hemicordulia australiae	Australian Emerald	widespread
Hemicordulia superba (P)	Superb Emerald	SE Qld
Hemicordulia tau	Tau Emerald	widespread
Procordulia jacksoniensis	Eastern Swamp Emerald	Granite Belt
Family Libellulidae		
Aethriamanta circumsignata	Square-spot Basker	widespread
Diplacodes bipunctata	Wandering Percher	widespread
Diplacodes haematodes	Scarlet Percher	widespread
Diplacodes melanopsis	Black-faced Percher	SE Qld
Nannophya australis	Australian Pygmyfly	widespread
Nannophya dalei	Eastern Pygmyfly	Granite Belt
Orthetrum caledonicum	Blue Skimmer	widespread
Orthetrum villosovittatum	Fiery Skimmer	widespread
Pantala flavescens (O)	Wandering Glider	widespread
Libelluloidea incertae sedis		
Austrocordulia refracta	Eastern Hawk	widespread
Cordulephya pygmaea	Common Shutwing	SE Qld, Clarke Ra. Carnarvon Gorge

a tributary of the same creek. *Episynlestes albicauda* occurs in north-east New South Wales and south-eastern Queensland as far north as about Rockhampton, with an isolated population at Carnarvon Gorge. *Synlestes weyersii* is distributed from Victoria through eastern New South Wales to the extreme south-eastern corner of Queensland, where it is largely restricted to the Granite Belt and nearby areas of the Scenic Rim. Like *E. albicauda*, there is also an isolated population of *S. weyersii* at Carnarvon Gorge further to the north-west. In the Granite Belt, *S. weyersii* has been collected and photographed at a number of localities including Racecourse, Quart Pot and Bald Rock Creeks in Girraween NP and The Broadwater.

Family Lestidae

Lestids are represented in the Granite Belt by four species of *Austrolestes* Tillyard, a genus that is most diverse in southern Australia. One species, *Austrolestes leda* (Selys) (Wandering Ringtail), is relatively widespread in eastern Australia and

occurs as far north as the Wet Tropics Bioregion in Queensland.

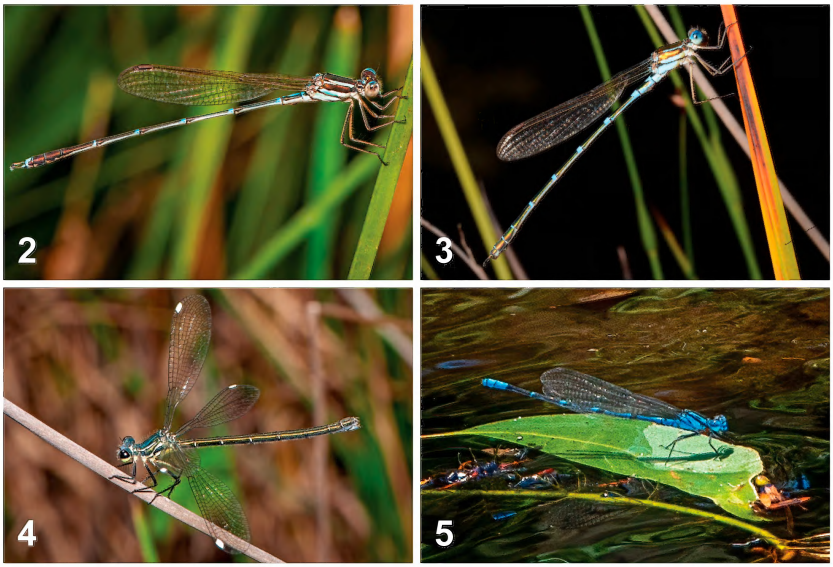
The remaining three species are essentially confined to southern Australia with the extreme south-east corner of Queensland representing the northern-most extent of their ranges. Reliable Queensland records of two of them, *Austrolestes analis* (Rambur) (Slender Ringtail) (Fig. 2) and *Austrolestes cingulatus* (Burmeister) (Metallic Ringtail) (Fig. 3), are confined to the Granite Belt. The handful of records of *A. analis* from the Granite Belt are from swamps within Girraween NP, including Goebels Swamp on Pyramids Road (NPP and DW photographs) and Dingo Swamp (QM specimen). Similarly, reliable Queensland records of *A. cingulatus* are confined to Girraween NP; Dingo Swamp, along the Mt Norman Road, and Bald Rock Creek. Two specimens of *A. cingulatus* in the Queensland Museum collected in 1930 are labelled as from 'Stanthorpe' but we feel they were likely collected elsewhere in the Granite Belt. In Queensland, the third species, *Austrolestes psyche* (Hagan) (Cup Ringtail) is known from the headwaters of Racecourse and Paling Yard Creeks in Girraween NP in the Granite Belt but there are also two old specimen records from the Gold Coast hinterland (Lamington and Springbrook NPs, QM) and more recent records from the sand islands of Moreton Bay; Moreton (QM specimen) and North Stradbroke Islands (Arthington and Watson 1982).

Family Lestoideidae

Two species of *Diphlebia* Selys are known from the Granite Belt, *Diphlebia coerulescens* Tillyard (Sapphire Rockmaster) and *Diphlebia nymphoides* Tillyard (Arrowhead Rockmaster) (Fig. 10). *Diphlebia coerulescens* occurs in far north-eastern New South Wales and south-eastern Queensland as far north as the Sunshine Coast hinterland, with substantial gaps in its distribution to populations at Kroombit Tops (HBH unpublished records) and the Clarke Range (Burwell et al. 2020) in central Queensland. Records of the species in the Granite Belt are sparse, it having been observed along Bald Rock Creek in Girraween NP and collected at Passchendaele. The second species, *D. nymphoides*, occurs from eastern Victoria north through eastern New South Wales and south-eastern Queensland north to Mt Wash NP (25°36'S 152°03'E) with a disjunct population at Carnarvon Gorge Queensland. Records of the species in the Granite Belt are also scarce and include specimens from Fletcher (Australian Museum) and Stanthorpe (Museum of Victoria) and a photographic record from Stanthorpe (most probably Quart Pot Creek, MGJ). A third species, *Diphlebia lestoides* (Selys) (Whitewater Rockmaster) may also occur in the region as there is an observation of the species from the Severn River in Sundown NP (Reiner Richter record ALA) just to the west of the Granite Belt. *Diphlebia lestoides* is distributed from Victoria north through eastern New South Wales to the extreme south-east corner of Queensland.

Family Platycnemididae

The family Platycnemididae is represented in Australia by twelve species of *Nosoticta* Hagan, most of which are confined to northern Australia. *Nosoticta*



Figs 2–5. Damselfly species restricted to the Granite Belt in Queensland. (2) *Austrolestes analis*, Slender Ringtail, male from Goebels Swamp, Girraween NP (NPP/DW). (3) *Austrolestes cingulatus*, Metallic Ringtail, male from Racecourse Creek, Girraween NP (CJB). (4) *Griseargiolestes eboracus*, Grey-chested Flatwing, female from Goebels Swamp, Girraween NP (NPP/DW). (5) *Caliagrion billinghursti*, Large Riverdamsel, male from Bald Rock Creek, Girraween NP (NPP/DW).

solida (Hagan) is the only species recorded from the Granite Belt and is the most widespread Australian *Nososcticta* species, extending from Cape York Peninsula in Queensland south to Victoria and south-east South Australia. It inhabits flowing streams and rivers and is likely to occur in suitable habitat throughout the Granite Belt.

Family Isostictidae

To date, the only isostictid species recorded from the Granite Belt is *Rhadinosticta simplex* (Martin) (Powdered Wiretail) which is widespread in eastern Australia from the Wet Tropics Bioregion in Queensland south to Victoria. There are two specimen-based records (both QM) and photographic records (NPP and DW) from the Granite Belt from Bald Rock Creek in Girraween NP and The Broadwater, Amiens. *Rhadinosticta simplex* inhabits streams and rivers and is an inconspicuous, dull-coloured damselfly that hangs from streamside vegetation.

Family Argiolestidae

Three argiolestid species have been recorded from the Granite Belt, *Austroargiolestes amabilis* (Förster) (Flame Flatwing), *Austroargiolestes*

icteromelas (Selys) (Common Flatwing) and *Griseargiolestes eboracus* (Tillyard) (Grey-chested Flatwing) (Fig. 4). *Austroargiolestes amabilis* occurs in north-eastern New South Wales and south-eastern Queensland from Barrington Tops north to Mt Tambourine and Main Range NP (Theischinger and O'Farrell 1986, QM specimen records). Specimen records of the species from the D'Aguilar Range and the Sunshine Coast hinterland (Australian National Insect Collection (ANIC) sourced using the ALA) are questionable and are likely to be the similar *Austroargiolestes chrysoides* (Golden Flatwing). There is only one record of the species from the Granite Belt; a single specimen observed by RGH along Racecourse Creek at South Bald Rock in Girraween NP. There are photographic records of the species about 6 km to the north-east from Bald Rock NP in New South Wales (ALA). *Austroargiolestes icteromelas* is widespread in eastern Australia occurring from the northern Wet Tropics bioregion south to Victoria. Two subspecies are recognised. The nominate subspecies, *A. i. icteromelas* (Selys), has a largely pale-coloured labium and occurs in the more southern and cooler parts of the species' range. *Austroargiolestes i. nigrolabiatus* Theischinger and O'Farrell has a largely dark-coloured labium and occurs in the more northern and warmer parts of its range. North-eastern New South Wales and south-eastern Queensland appear to be the regions where one subspecies transitions to the other, and both subspecies co-occur on the Springbrook Plateau in Queensland (CJB pers. obs.). All specimens that we have examined from the Granite Belt are the nominate subspecies with the pale labium. The vast majority of specimens from the Granite Belt have been collected within Girraween NP, however the species is likely to found along streams and rivers throughout the region.

Griseargiolestes eboracus inhabits boggy seepages and sphagnum bogs and occurs from north-eastern Victoria (Richter and Endersby 2019, G. Theischinger pers. comm.), north throughout coastal New South Wales to south-eastern Queensland. The species' range narrowly extends into Queensland where it appears restricted to the Granite Belt with records confined to Girraween NP, most from swamps bordering creeks in the vicinity of Mt Norman and South Bald Rock.

Family Coenagrionidae

Coenagrionidae is the most diverse family of damselflies in Australia, but is poorly represented in the Granite Belt where six species have been recorded. Of these, five are widely distributed in Australia. *Ischnura heterosticta* (Burmeister) (Common Bluetail), *Ischnura aurora* (Brauer) (Aurora Bluetail) and *Xanthagrion erythroneurum* (Selys) (Red and Blue Damsel) occur throughout Australia, including Tasmania, while *Austroagrion watsoni* Lieftinck (Blue Billabongfly) and *Pseudagrion aureofrons* Tillyard (Gold-fronted Riverdamsel) occur through much of northern and eastern Australia. Most inhabit both standing and slow-flowing aquatic habitats and both species of *Ischnura* are capable of breeding in temporary pools. *Pseudagrion aureofrons* is more strongly associated with riverine habitats, including streams, rivers and riverine pools and lagoons. All five species are likely to occur in suitable habitats throughout the Granite Belt.

Figs 6–8. Dragonfly species restricted to the Granite Belt in Queensland. (6) *Austroaeschna parvistigma*, Swamp Darner, male and female in wheel position beside Underground Creek, Girraween NP (MGJ). (7) *Telephlebia godeffroyi*, Eastern Evening Darner, female from The Pyramid, Girraween NP (Don Gardner). (8) *Synthemis eustalacta*, Swamp Tigertail, male from Goebels Swamp, Girraween NP (NPP/DW).

The remaining species, *Caliagrion billinghursti* (Martin) (Large Riverdamsel) (Fig. 5) occurs in Victoria and eastern New South Wales. The species' distribution narrowly extends into Queensland with records confined to the Granite Belt; two males collected from The Broadwater near Amiens in January 1981 (QM) and observational records of multiple individuals from Bald Rock Creek in Girraween NP in February 2017 (with accompanying photographs) and Quart Pot Creek in Stanthorpe in early 2019 (NPP and DW).

Suborder Anisoptera (Dragonflies)

Family Aeshnidae

To date, eight aeshnid species have been recorded from the Granite Belt. Three belong to subfamily Aeshninae (sensu Carle et al. 2015) and all are very widespread in Australia and generally inhabit standing-water habitats; *Adversaeschna brevistyla* (Rambur) (Blue-spotted Hawker), *Anax papuensis* (Burmeister) (Australian Emperor) and *Austrogynacantha heterogena* Tillyard (Australian Duskhawker). Of these three species, *A. brevistyla* is largely distributed in the southern half of the country and is the most common aeshnid in the Granite Belt based on numbers of specimens in collections. There are few specimen records

of *A. papuensis* from the Granite Belt, most from Girraween NP, but this species is likely to occur throughout the region. The only record of the crepuscular *A. heterogena* from the Granite Belt is a single specimen collected from a tributary of Bald Rock Creek in Girraween NP (QM).

The remaining five aeshnid species from the Granite Belt belong to the subfamily Telephlebiinae (sensu Carle et al. 2015) and are typically associated with streams and rivers; *Austroaeschna parvistigma* (Selys) (Swamp Darner) (Fig. 6), *Austroaeschna pulchra* Tillyard (Forest Darner), *Austroaeschna unicornis* (Martin) (Unicorn Darner) (Fig. 9), *Austrophlebia costalis* (Tillyard) (Southern Giant Darner) and *Telephlebia godeffroyi* Selys (Eastern Evening Darner) (Fig. 7).

There is a single photographic record of *A. parvistigma* from the Granite Belt, a pair in the wheel position beside Underground Creek (part of Bald Rock Creek) in Girraween NP in early May 2012 (MGJ). This appears to be only record of the species from Queensland; it was not recorded from Queensland by Watson (1974), Watson et al. (1991) or Theischinger and Hawking (2006) and there do not appear to be any Queensland records on the distribution map of the species in Theischinger and Endersby (2009). Otherwise recorded from south-eastern South Australia, Tasmania, Victoria and throughout eastern New South Wales, *A. parvistigma* inhabits rivers and small streams that are predominantly slow-flowing and heavily vegetated (Theischinger and Hawking 2006).

Austroaeschna pulchra ranges from Victoria north through eastern New South Wales and south-eastern Queensland as far north as the Bunya Mountains and the Sunshine Coast hinterland. There are only two specimen records from the Granite Belt, both from Girraween NP; a female from a tributary of Bald Rock Creek and a male from Beehive Gully adjacent to the Mt Norman Road, both collected in January 2002 (QM).

The third species of *Austroaeschna* from the region is *A. unicornis*, represented by a single male collected along Bald Rock Creek, Girraween NP (QM) in 2014 (Fig. 9). *Austroaeschna unicornis* occurs in south-eastern Australia from south-east South Australia and from Tasmania north through Victoria and eastern New South Wales. The distribution of this species in Queensland is uncertain due to confusion surrounding the relationship of *A. unicornis* with the very similar *Austroaeschna pinheyi* Theischinger (Inland Darner). The latter species was originally described as a subspecies, *A. unicornis pinheyi*, from specimens from Carnarvon Gorge and south-eastern Queensland to the west of the Great Dividing Range although one paratype was from Crows Nest Falls to the east of the divide (Theischinger 2001). Theischinger and Hawking (2006) treated *pinheyi* as a subspecies of *A. unicornis* but the following year Peters and Theischinger (2007) raised it to species level. Theischinger and Hawking (2006) noted that *A. pinheyi* (as *A. unicornis pinheyi*) occurred in the more montane areas of southern Queensland, and after discussions with Günther Theischinger we suspect that all *unicornis*-like specimens from coastal south-eastern Queensland are also likely to be *A. pinheyi*. According to Theischinger and Hawking (2006) *A. unicornis*

Fig. 9. Preserved *Austroaeschna unicornis*, Unicorn Darner, male collected from Bald Rock Creek, Girraween NP.

(as *A. u. unicornis*) occurs in eastern Australia south of the Qld/NSW border, i.e. they considered it did not occur in Queensland. The single male from Girraween NP (Fig. 9), however, closely matches Theischinger and Hawking's (2006) descriptions and illustrations of *P. unicornis unicornis* and thus may be the only record of 'true' *A. unicornis* from Queensland.

A male *T. godeffroyi* was collected from a tributary of Bald Rock Creek within Girraween NP in January 2002 (QM) and another specimen was photographed by Don Gardner in December 2011 on The Pyramid at Girraween NP (Fig. 7). As far as we are aware, these are the only Queensland records of the species which is otherwise known from eastern New South Wales. Theischinger (1985), in his revision of *Telephlebia*, did not list any specimens of *T. godeffroyi* from Queensland and Watson (1974) and Watson et al. (1991) only listed the species from New South Wales. Theischinger and Hawking (2006), however, included south-eastern Queensland in the distribution of *T. godeffroyi*, presumably based on the above-mentioned specimen collected in 2002.

Austrophlebia costalis is an enormous, stream-dwelling dragonfly distributed from east Gippsland, Victoria, north through eastern New South Wales and south-eastern Queensland as far as the Bunya Mountains and the Sunshine Coast hinterland with a disjunct population in the Clarke Range of central coastal Queensland (Burwell et al. 2020). There is only a single record of the species from the Granite Belt, a male collected from Beehive Gully, a tributary of

Accommodation Creek adjacent to the Mt Norman Road in Girraween NP (QM).

Family Petaluridae

HBH and RGH believe they observed a male *Petalura gigantea* Leach (South-eastern Petaltail), in Girraween NP at Dingo Swamp near South Bald Rock in April 2002. They were unable to collect or photograph the specimen and thus the record is unsubstantiated. However, the only other species of comparable size and colour in the region is *Austrophlebia costalis* which lacks the paddle-shaped superior anal appendages that are characteristic of the males of *Petalura* Leach species. An unsubstantiated observation of the species in the same area was made by Michael Mathieson (date of the observation was not recorded M. Mathieson pers. comm.) which was the basis of Baird (2014) recording the species from south-eastern Queensland. This species occurs in eastern New South Wales from near Nadgee, very close to the New South Wales border with Victoria, north to north-eastern New South Wales at Basket Swamp NP and Boonoo Boonoo SF. The larvae of *P. gigantea* are fossorial, occupying permanent burrows in ground-water dependent mires (Baird 2014, Baird and Burgin 2016). Dingo Swamp is probably suitable habitat for the species in Queensland. Only 12 km separates Dingo Swamp in Girraween NP from Basket Swamp in New South Wales where *P. gigantea* is highly likely to be resident and the species may also occur in Bald Rock NP (NSW) in the intervening area. Thus the occurrence of the species in Queensland in the eastern part of Girraween NP is not unexpected.

Family Gomphidae

Gomphids are well represented in the Granite Belt with eight species recorded from the region, five species of *Austrogomphus* Selys, two species of *Hemigomphus* Selys and a single *Austroepigomphus* Fraser species.

Of the *Austrogomphus* species, there are relatively few records of two species; *A. australis* Dale (Inland Hunter) and *A. cornutus* Watson (Unicorn Hunter) (Fig. 11). *Austrogomphus australis* is associated with inland rivers and riverine pools in south-eastern Australia. There are no recent records of the species from the Granite Belt with two specimens from Stanthorpe collected in 1924 and a single specimen from Fletcher collected in 1955 (all in ANIC). There are two specimen records of *A. cornutus* from the Granite Belt, one from Stanthorpe from 1930 (ANIC) and another from The Broadwater from 1981 (QM) and a photographic record from Quart Pot Creek, Stanthorpe in December 2006 (MGJ, Fig. 11). It is associated with streams and rivers occurring from south-eastern South Australia and Victoria north through eastern New South Wales as far north as Charters Towers in central Queensland.

The three remaining *Austrogomphus* species, *A. amphiclitus* (Selys) (Pale Hunter), *A. guerini* (Rambur) (Yellow-striped Hunter) (Fig. 12) and *A. ochraceus* (Selys) (Jade Hunter) (Fig. 13) are more common in the Granite Belt with numerous specimen records of each from the region. All three inhabit streams and rivers,

Figs 10–13. Lestoideidae (Fig. 10) and Gomphidae (Figs 11–13) species from the Granite Belt. (10) *Diphlebia nymphoides*, Arrowhead Rockmaster, male from Bald Rock Creek, Girraween NP (NPP/DW). (11) *Austrogomphus cornutus*, Unicorn Hunter, male from Quart Pot Creek, Stanthorpe (MGJ). (12) *Austrogomphus guerini*, Yellow-striped Hunter, male from Bald Rock Creek, Girraween NP (CJB). (13) *Austrogomphus ochraceus*, Jade Hunter, male from Bald Rock Creek, Girraween NP (CJB).

although *A. ochraceus* is also associated with lakes. *Austrogomphus amphiclitus* is the most-northerly distributed species of the three, occurring throughout eastern New South Wales and Queensland as far north as the Wet Tropics with the other two species essentially confined to south-eastern Australia. *Austrogomphus ochraceus* occurs from eastern Victoria, throughout eastern New South Wales and in Queensland is confined to the south-eastern corner as far north as the Sunshine Coast hinterland. *Austrogomphus amphiclitus* and *A. ochraceus* are likely to occur throughout the Granite Belt in suitable habitat with records of both from Girraween NP, The Broadwater and Fletcher. Of the five *Austrogomphus* species known from the Granite Belt, *A. guerini* has the most restricted distribution in Queensland. It occurs in south-eastern South Australia and Tasmania and Victoria north through eastern New South Wales. Its distribution narrowly extends into south-eastern Queensland where it is common in Girraween NP having been recorded from numerous localities within the park. There are no records of the species from elsewhere in the Granite Belt, however it is likely to be more widespread. The few reliable records of *A. guerini* from beyond the Granite Belt are confined to streams on the western side of the Great Diving Range; Goomburra and Upper Emu Creek in Main Range NP (Watson 1991 and specimens in QM).

There are several records of *Austroepigomphus praeruptus* (Selys) (Twin-spot Hunter) from the Granite Belt, all from creeks and rivers; Bald Rock and Paling Yard Creeks (Girraween NP), The Broadwater and Severn River (Glen Aplin) (specimens in QM and ANIC). This species is widespread in Queensland with records from the Wet Tropics south to south-eastern Queensland and extends through eastern New South Wales to Victoria and south-eastern South Australia.

The remaining gomphid species recorded from the Granite Belt are two very similar species of *Hemigomphus*, *H. gouldii* (Selys) (Southern Vicetail) and *H. heteroclytus* Selys (Stout Vicetail), the males of which are distinguished by subtle differences in the shape of the superior anal appendages. *Hemigomphus gouldii* occurs from Victoria through eastern New South Wales and as far north as south-eastern Queensland, while *H. heteroclytus* occurs throughout eastern New South Wales and extends through eastern Queensland as far north as the Wet Tropics. The two species therefore overlap extensively, throughout New South Wales and south-eastern Queensland. Although both species have been recorded from the Granite Belt, they have not been found to co-occur. All records of *H. gouldii* in the region are from Racecourse Creek and the associated Dingo Swamp in Girraween NP, with most collected in January in 2000 and 2001. *Hemigomphus heteroclytus* has also been collected from Girraween NP, but only from Bald Rock Creek, and from The Broadwater.

Family Synthemistidae

The family Synthemistidae, is well represented in the Granite Belt region with seven species.

Choristhemis flavoterminata (Martin) (Yellow-tipped Tigertail) is widespread in eastern Australia occurring from the border of Victoria and New South Wales north to the Wet Tropics, Queensland. There are numerous specimen-based records of the species from Girraween NP as well as Fletcher, Glen Aplin, Stanthorpe and The Broadwater (QM, ANIC). It inhabits streams and rivers and is likely to occur throughout the Granite Belt.

Parasynthemis regina Selys (Royal Tigertail) occurs from Victoria north through eastern New South Wales and south-eastern Queensland north to near to Sarina in central coastal Queensland. There are a handful of records of the species from the Granite Belt including from Dingo Swamp in Girraween NP, Stanthorpe and Fletcher.

Synthemis eustalacta (Burmeister) (Swamp Tigertail) (Fig. 8) inhabits swamps and boggy seepages and occurs in south-eastern Australia from south-east South Australia and Victoria north throughout eastern New South Wales as far the border with Queensland. Its distribution extends into Queensland where it is likely restricted to the Granite Belt; all specimens have been collected from Girraween NP, usually associated with swamps. The species is relatively common in suitable habitat within the park, with specific localities including Goebels Swamp on Pyramids Road, Dingo Swamp, swampy areas along Quart Pot Creek, and

Figs 14–17. Libelluloidea incertae sedis (Fig. 14), Corduliidae (Fig. 15) and Libellulidae (Figs 16, 17) species from the Granite Belt. (14) *Cordulephya pygmaea*, Common Shutwing, male from Mt Marlay (MGJ). (15) *Hemicordulia superba*, Superb Emerald, male from Mt Marlay (MGJ). (16) *Aethriamanta circumsignata*, Square-spot Basker, male from Quart Pot Creek, Stanthorpe (MGJ). (17) *Nannophya australis*, Australian Pygmyfly, male from Goebels Swamp, Girraween NP (NPP/DW).

slow flowing sections of Bald Rock Creek and its tributaries. *Archaeosynthemis orientalis* Tillyard (Eastern Brown Tigertail) also inhabits swamps and boggy seepages, occurring from Tasmania north to the extreme south-east corner of Queensland. Like *S. eustalacta*, all records of *A. orientalis* from Queensland are from the Granite Belt, although there are records both from within Girraween NP (Dingo Swamp, Paling Yard Creek) and beyond the park (Mt Marlay, Amiens).

Three species of *Eusynthemis* Förster have been recorded from the Granite Belt; *E. aurolineata* (Tillyard) (Variable Tigertail), *E. nigra* (Tillyard) (Black Tigertail) and *E. virgula* (Selys) (Golden Tigertail). *Eusynthemis aurolineata* occurs in north-eastern New South Wales north from about Barrington Tops to south-eastern Queensland north to about the Conondale Ranges. Its distribution in Queensland is curious, occurring in swamps in the Granite Belt and streams in rainforest in the Bunya Mountains and more coastal ranges. All records of *E. aurolineata* from the Granite Belt are from Girraween NP with the vast majority from Dingo Swamp. *Eusynthemis virgula* is a stream-inhabiting species that occurs from Victoria north through eastern New South Wales. A single female of

E. virgula collected in February 2014 from Bald Rock Creek within Girraween NP is also the only record of the species from the Granite Belt and the only record from Queensland. *Eusynthemis nigra* is a stream-inhabiting species that occurs from north-eastern New South Wales, through eastern Queensland as far north as the Wet Tropics. There is only a single record of the species from the Granite Belt, a female collected from Stanthorpe in 1957 in Museum Victoria.

Family Corduliidae

Four corduliid species have been recorded from the Granite Belt region, three species of *Hemicordulia* Selys and a species of *Procordulia* Martin. Two of the *Hemicordulia* species occur widely in Australia including in Queensland, with *H. tau* (Selys) (Tau Emerald) distributed Australia-wide and *H. australiae* (Rambur) (Australian Emerald) occurring from the Wet Tropics, Queensland, south to Tasmania, as well as in south-eastern South Australia and south-western Western Australia. Both species occupy a variety of flowing and standing water habitats and are likely to occur throughout the Granite Belt. *Hemicordulia superba* Tillyard (Fig. 15) has a more restricted distribution in eastern New South Wales and south-eastern Queensland and the only record of the species from the Granite Belt is a photograph of a male from Mt Marlay on the eastern side of Stanthorpe taken in December 2008 (MGJ, Fig. 15).

The remaining corduliid species, *Procordulia jacksoniensis* (Rambur) (Eastern Swamp Emerald), occurs in south-eastern Australia, from south-eastern South Australia east to Victoria and Tasmania and north through eastern New South Wales. Its distribution narrowly extends into the extreme south-eastern corner of Queensland where it appears relatively common in swamps in the east of Girraween NP including Dingo Swamp. We suspect that in Queensland *P. jacksoniensis* is confined to the Granite Belt and consider a specimen from Ipswich (ANIC) as probably mislabelled.

Family Libellulidae

Libellulidae is the most speciose Australian family of dragonflies but is poorly represented in the Granite Belt with nine species recorded to date. There has been relatively little survey effort devoted to open, standing water habitats in the Granite Belt and targeted collecting at lakes, lagoons and farm dams is likely to yield several additional libellulid species for the region.

There is only a single record of *Aethriamanta circumsignata* Selys (Square-spot Basker) from the Granite Belt, a male photographed by MGJ about 1.7 km north-west of Ballandean (Fig. 16). Essentially a northern species, occurring in the north of the Northern Territory and eastern Queensland from the Wet Tropics to south-eastern Queensland and far north-eastern New South Wales, this species is unlikely to be a resident of the Granite Belt.

Three species of *Diplacodes* Kirby have been recorded from the Granite Belt. Two, *D. bipunctata* (Brauer) (Wandering Percher) and *D. haematodes*

(Burmeister) (Scarlet Percher) occur throughout Australia while *D. melanopsis* (Martin) (Black-faced Percher) occurs from Victoria north throughout eastern New South Wales to south-eastern Queensland. There are multiple specimen and photographic/observational records of all three species from the Granite Belt.

Two species of *Nannophya* Rambur, tiny dragonflies that generally inhabit boggy seepages and swamps, have been collected from the Granite Belt; *N. australis* Brauer (Australian Pygmyfly) (Fig. 17) and *N. dalei* (Tillyard) (Eastern Pygmyfly). The former is widespread in Queensland occurring from Cape York Peninsula to south-eastern Queensland, extending through eastern New South Wales to eastern Victoria. It has been photographed from Goebels Swamp (NPP/DW) and collected in the vicinity of Mt Norman in Girraween NP (QM) (Fig. 17). In contrast, *N. dalei* is restricted to southern Australia, occurring from south-eastern South Australia, Tasmania and Victoria north through eastern New South Wales. Watson (1974), Watson et al. (1991) and Theischinger and Hawking (2006) did not record *N. dalei* from Queensland and there does not appear to be any Queensland records on the distribution map of the species in Theischinger and Endersby (2009). However, the range of *N. dalei* narrowly extends into Queensland where it appears restricted to the Granite Belt, in particular to swamps in Girraween NP. There are nine specimens of *N. dalei*, in the Queensland Museum, five males and four females, all from Dingo Swamp, Girraween NP. All were collected in January in either 2000 or 2001.

Two species of *Orthetrum* Newman are known from the Granite Belt where they are likely to occur in a wide range of standing- and flowing-water habitats throughout the region. Both species are widespread in Australia. *Orthetrum caledonicum* (Brauer) (Blue Skimmer) is one of the commonest dragonflies throughout mainland Australia while *Orthetrum villosovittatum* (Brauer) (Fiery Skimmer) occurs in the Top End of the Northern Territory and eastern Australia from the Torres Strait south to Victoria.

Finally, *Pantala flavescens* (Fabricius) (Wandering Glider), which occurs throughout mainland Australia is recorded from the Granite Belt based on a single observation at Bald Rock Creek, Girraween NP by RGH in December 2017.

Libelluloidea incertae sedis

The crepuscular *Austrocordulia refracta* Tillyard (Eastern Hawk) is represented in the Granite Belt by one female collected from a tributary of Bald Rock Creek in Girraween NP in January 2002 (QM). This species inhabits streams, rivers and riverine pools and is widely distributed in eastern coastal mainland Australia from East Gippsland in north-east Victoria north to the Wet Tropics, Queensland.

Cordulephya pygmaea Selys (Common Shutwing) (Fig. 14) occurs from Victoria north through eastern New South Wales to south-eastern Queensland. There are apparently isolated populations of the species at Carnarvon Gorge and the Clarke

Range in Queensland but additional specimens are required to assess if they are conspecific with those from southern Australia (Burwell et al. 2020). There are several of records of *C. pygmaea* from the Granite Belt with photographic and observational records outnumbering specimens in collections. Localities for the species in the Granite Belt include Stanthorpe, Broadwater SF, Bald Rock Creek in Girraween NP, and near Ballandean. Based on the records from the region, the species appears to be active in early to mid-autumn (late March to early May).

Discussion

More than half of the species recorded from the Granite Belt are widespread in Australia including Queensland, especially those associated with standing water habitats such as dams, lakes and ephemeral ponds (Table 1). This element of the odonate fauna probably represents an even greater proportion of the regional fauna given that these types of lentic habitats appear to have been poorly sampled in the Granite Belt. For example there have been no collections of dragonflies and damselflies from Storm King Dam, the largest artificial lake in the region.

A substantial proportion of the Granite Belt damselfly and dragonfly fauna, however, consists of species largely restricted to south-eastern Australia that extend north only as far as south-eastern Queensland. Some extend well into south-eastern Queensland, often as far north as the Sunshine Coast hinterland, sometimes with isolated populations in central-coastal Queensland (Kroombit Tops, Clarke Range) or Carnarvon Gorge (Table 1). Numerous species, however, only narrowly extend into south-eastern Queensland, including many restricted to the Granite Belt (Table 1). Thus, for around a fifth of the region's species, the Granite Belt is their northern range limit. Among the damselflies these include *Austrolestes analis* and *Austrolestes cingulatus* (Lestidae), *Caliagrion billinghursti* (Coenagrionidae) and *Griseargiolestes eboracus* (Argiolestidae), while the dragonflies include *Telephlebia godeffroyi*, *Austroaeschna parvistigma* and possibly *Austroaeschna unicornis* (Aeshnidae), *Petalura gigantea* (Petaluridae), *Archaeosynthemis orientalis*, *Synthemis eustalacta* and *Eusynthemis virgula* (Synthemistidae), *Procordulia jacksoniensis* (Corduliidae) and *Nannophya dalei* (Libellulidae). Of these species, several are mostly stream-associated *viz. C. billinghursti*, *A. parvistigma*, *T. godeffroyi* and *E. virgula*, most of which are known from only one or two collections or observations in the Granite Belt. Given the paucity of records it is questionable whether these species maintain long-term populations in the region. However, at least one species, *Caliagrion billinghursti*, appears likely to be resident in the region, and the stream and river systems of the Granite Belt support populations of other biogeographically significant aquatic fauna. For example, in Queensland streams in the Girraween area, as well as the headwaters of Condamine on the western side of Main Range, harbour highly disjunct populations of the River Blackfish, *Gadopsis marmoratus* Richardson, which is widespread in south-eastern Australia with the nearest populations occurring just north of Armidale (ALA). Similarly the Mountain Galaxias, *Galaxias olidus*

Günther which is widespread in temperate south-eastern Australia on both sides of the Great Dividing Range (Raadik 2014), has a very restricted distribution in Queensland and is known from Girraween, the headwaters of the Condamine and also the headwaters of the Logan and Albert Rivers in the Gold Coast hinterland (Hines et al. 2019). Bald Rock Creek in Girraween NP harbours the only known Queensland population of Bell's Saw-shell Turtle, *Wollumbinia belli* (Gray), which otherwise occurs in the Northern Tablelands region of New South Wales in the headwaters of rivers on the western side of the Great Dividing Range (Cann and Sadlier 2017).

Six of the dragonfly and damselfly species restricted to the Granite Belt in Queensland are strongly associated with swamps and wet heaths in Girraween NP; *A. cingulatus*, *G. eboracus*, *S. eustalacta*, *A. orientalis*, *P. jacksoniensis* and *N. dalei*. Unlike the stream-inhabiting species mentioned above, most have been frequently collected or observed in swamps in the wetter, south-eastern part of the park, especially along Racecourse, Paling Yard and Quart Pot Creeks. These areas almost certainly provide breeding habitat for the species and are likely critical for their persistence in Queensland. *Petalura gigantea* could also potentially breed in these swamps, but the presence of the species in Girraween NP, and thus Queensland, is unconfirmed; the two observations of the species in the park were not substantiated by photographs or specimens. These high elevation swamps, as well as streams in the national park, are also habitat for the New England Tree Frog, *Litoria subglandulosa* Tyler and Anstis, and the New England Crayfish, *Euastacus suttoni* Clark. The tree frog occurs above 600m asl in the ranges from near Walcha in north-eastern New South Wales north to south-eastern Queensland where it is restricted to Girraween NP (Anstis 2017, Clulow and Swan 2018). The crayfish reaches its northern limit and has its stronghold in Girraween NP in Queensland. It otherwise occurs south to Glen Innes, NSW, in both eastern and western drainages in tributaries of the Dumaresq, Severn, Deepwater, Timbarra and Clarence Rivers (McCormack 2012).

The persistence in Queensland of the dragonfly and damselfly species restricted to the Granite Belt is at risk due to climate change. When discussing the possible impacts of climate change on species at their northern range limits in the Granite Belt, Low (2011) suggested that some reptile species at least may be buffered against rising temperatures by seeking refuge in rock crevices during heat-waves while others may not be living at the limits of their thermal tolerances. However, rising temperatures combined with changes in rainfall patterns, particularly more severe and prolonged droughts, are likely to strongly impact species associated with aquatic habitats or moist microhabitats in the region, such as the New England Tree Frog, Bell's Turtle and the Mountain Galaxias (Low 2011). Dragonfly and damselfly species are also likely to be more severely affected; altered flow rates could impact the stream-associated species and changes to ground-water levels in the wet heaths in the eastern parts of Girraween NP may impact swamp-associated species. For example the ground-water dependent mire species *Petalura gigantea*, if indeed it breeds in Girraween NP, is likely to be

impacted by multiple stressors due to climate change including a lowering of the water table combined with more severe and increased fire frequency (Baird and Burgin 2016). Monitoring the condition of aquatic habitats within Girraween NP, combined with appropriate management of fire regimes in the face of a changing climate may be critical for the persistence of Granite Belt restricted dragonfly and damselfly species in Queensland.

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A NEW SPECIES OF *YOYETTA* MOULDS FROM SOUTH-EASTERN AUSTRALIA WITH NOTES ON RELATIONSHIPS WITHIN THE *YOYETTA TRISTRIGATA* SPECIES GROUP (HEMIPTERA, CICADIDAE, CICADETTINI)

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Abstract

Yoyetta robertsonae **sp. n.** is described from the Central and Southern Tablelands of New South Wales, the Australian Capital Territory and Victoria. Its song is analysed and compared with that of other *Yoyetta* Moulds species. *Yoyetta robertsonae* forms part of the *Y. tristrigata* species group and a morphological cladistic analysis is employed to investigate the phylogenetic relationships of this group.

Key words: cicada songs, Cicadoidea, Auchenorrhyncha, phylogeny, taxonomy

Introduction

The genus *Yoyetta* Moulds, 2012 includes more than 30 species (Moulds 2012, Emery *et al.* 2015, 2019; Moulds and Popple 2018; Sanborn 2013), widely distributed through eastern and central Australia. They are small cicadas, the males of most species having characteristic orange markings on the abdomen. The genus has been fully defined by Moulds (2012) and Emery *et al*. (2015). Emery *et al*. (2015, 2019) provide keys to the described species.

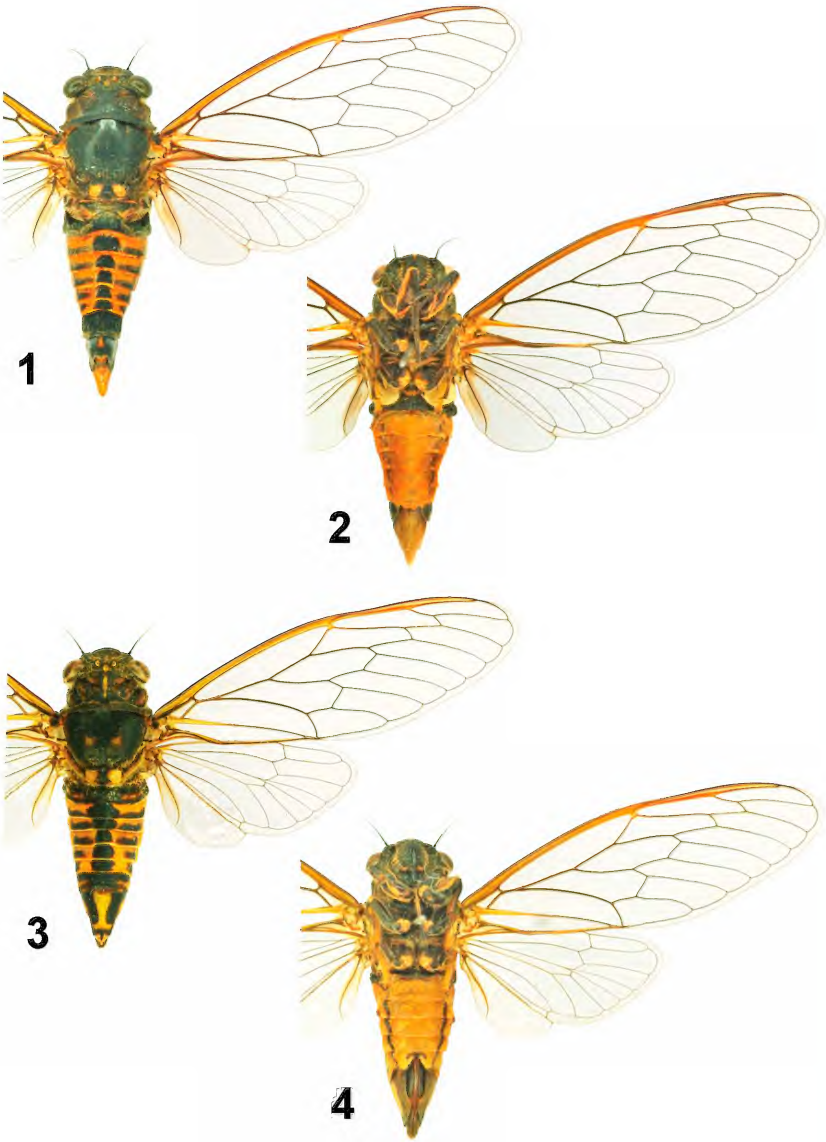
Here we describe another species, *Yoyetta robertsonae* **sp. n.**, a common species found throughout much of the Central and Southern Tablelands (as defined by Bureau of Meteorology 2020) of New South Wales, the Australian Capital Territory and in Victoria. It falls within the *Y. tristrigata* species group of Emery *et al*. (2015) that is defined as having abdominal tergites 2–7 mainly yellow-brown to orange-brown, and the hindwing plaga opaque and cream to light brown or orange-brown along the majority of the jugal fold and 50–100% of the outer margin. It includes eight other species: *Y. celis* (Moulds), *Y. cumberlandi* Emery, Emery & Popple, *Y. fluviatilis* Emery, Emery & Popple, *Y. landsboroughi* (Distant), *Y. humphreyae* Moulds & Popple, *Y. nigrimontana* Emery, Emery & Popple, *Y. repetens* Emery, Emery & Popple and *Y. tristrigata* (Goding & Froggatt). We discuss relationships within this group for the first time.

Morphological terminology follows that of Moulds (2005, 2012) for body and wing structures, Moulds (2012) for genitalia, and Bennet-Clark (1997) for timbals. Abbreviations for collections are: AE – Tony Ewart; AM – Australian Museum, Sydney; ANIC – Australian National Insect Collection, Canberra; DE – David Emery; LWP – Lindsay Popple; MSM – Max Moulds; QM – Queensland Museum, Brisbane; MV – Museum Victoria, Melbourne.

Tribe Cicadettini Buckton, 1890
Genus *Yoyetta* Moulds, 2012
***Yoyetta robertsonae* sp. nov.**
(Figs 1–15)

Type material. Holotype ♂, AUSTRALIAN CAPITAL TERRITORY: 17 Araba St, Aranda, [35°15'52"S 149°05'01"E, 1016m], 3.xii.2012, Susan Robertson, registration no. ANIC 20-007010 (in ANIC).

Paratypes. **NSW SOUTH WALES**: 1 ♀, Capertee, NSW, 33°08'25"S 149°58'47"E, 6.xii.2009, D. Emery (DE). 1 ♂, ~3km SE. of Captains Flat, 35°36'23"S 149°27'57"E, 5.xii.2009, L.W. Popple, 485-0030 (LWP). 1 ♀, Tuglow River, Mt Werong Fire trail, 23 Dec.1973, G. Daniels; 1 ♀, "Calosoma" via Gundaroo, 10 Dec.1978, B.P. Moore; 18 ♂♂, 17 ♀♀ (3 ♂♂ gen. preps YO36, YO37, YO39), Mt David, 30 km SW of Oberon, 26.xii.1985, S. & B. Underwood (MSM). **AUSTRALIAN CAPITAL TERRITORY:** 2 ♂♂, 17 Araba St, Aranda, 13.xii.2012, Susan Robertson (AE). 2 ♂♂, 17 Araba St, Aranda, 13.xii.2012, Susan Robertson (AM). 1 ♂ (registration no. ANIC 20-007011), 1 ♀ (registration no, ANIC 20-007012, Frith St, Acton, 35°16'14"S 149°06'48"E, 3–4.xii.2009, L.W. Popple, emerging, LT2009371, 485-0023, 485-0025 (ANIC). 2 ♂♂, Mt Ainslie, 20.xii.2001, D. Emery; 2♂♂, 4♀♀, Frith Rd, O'Connor, ACT, 35°16'07"S 149°06'32"E, 24.xi.2009, D. Emery & L. Popple; 2 ♂♂, 1 ♀, same location, 16–17.xii.2009, D. Emery & L. Popple (485-0004 [genitalia prep], 485-0012, -0018); 1 ♀, same location, 26.xii.2016, D. & C. Emery; 5 ♂♂, 1 ♀, Canberra, ANU campus, 35°16'29"S 149°07'06"E, 1–8.xii.2012, J. Slaney; 1 ♂, South Canberra, 24.xii.2014, J. Walker (DE). 3 ♂♂, 2 ♀♀, Crown Land (nr Jaeger Cct), Bruce, 35°15'09'S 149°05'00"E, 16–17.xi.2009, L.W. Popple, LT2009371, 485-0001 to 485-0003, 485-0005, 485-0006; 1 ♂, 1 ♀, ANBG fence, Acton, 35°16'26"S 149°06'39"E, 20.xi.2009, L.W. Popple, emerging [teneral], LT2009371, 485-0007, 485-0008; 1 ♂, 3 ♀♀ same data as previous, 25.xi.2009, 485-0010, 485-0011, 485-0016, 485-0017; 2 ♂♂, Belconnen Way, Aranda, 35°15'06"S 149°04'44"E, 26.xi.2009, A.D. Stewart, at light, LT2009371, 485-0019, 485-0020; 2 ♂♂, 5 ♀♀, Frith St, Acton, 35°16'14"S 149°06'48"E, 3–4.xii.2009, L.W. Popple, emerging, LT2009371, 485-0021, 485-0022, 485-0024,485-0026 to 285-0029; 1 ♂, Kaleen shops, 35°14'02"S 149°06'11"E, 5.xii.2009, L. Popple, A. Stewart, LT2009371, 485-0031; 1 ♂, Frith St, Acton, 35°16'14"S, 149°06'48"E, 5.xii.2010, L.W. Popple, LT2009371, 485-0032 (LWP). 2 ♂♂, Aranda, Canberra, 24–26.xii.2003, S. Robertson; 24 ♂♂ (1 gen. prep. YO43), 17 Araba St, Aranda, 30.xi, 3,5,9,13.xii.2012, Susan Robertson; 1 ♂, same locality, 10.xii.2003, S. & A. Robertson; 1 ♂, Canberra city, 25.xi.2014, S. Robertson; 4 ♂♂, Mt Ainslie, 2,3.i.1992, R. Eastwood (MSM). 2 ♂♂, Frith Road, Acton, 35°16'10"S 149°06'36"E, 2.xii.2016. L.W. Popple, netted, 485-0036, 485-0037 (QM). **VICTORIA:** 4 ♂♂, 4 ♀♀, Kinglake-Glenburn Rd., Kinglake, Vic, 32°28'1"S 145°23'41"E, 17.xii.2016, S. Emery & T. Corbin (emerging on grass); 1 ♂, 1 ♀, Westerfold Park, Templestowe, Vic, 37°45'02"S 145°07'04"E, 1–8.xii.2012, K. Green; 1 ♀, same location, 8.xii.2013, K. Green; 4 ♂♂, 3 ♀♀, same location, 16.xii.2016, S. Emery & T. Corbin; 1 ♂, ELZ, Kangaroo Ground Vic, 37°41'58"S 145°16'07"E, 9.xii.2015, F. Pierce (in Manna gums, *Eucalyptus viminalis*, along creek); 3 ♂♂, 3 ♀♀, Lions Park, Seymour, Vic, 37°01'56"S 145°07'33"E, 10.xii.2016; 1 ♂, 1 ♀, same location, 17.xi.2019, S. & T. Corbin; 7 ♂♂, 5 ♀♀, 1 km E Wangaratta, 36°21'16"S 146°20'45"E, 11.xi.2019, S. & T. Corbin, N. & D. Emery, C. Foster (emerging on grass and shrubs); 1 ♂, 1 ♀, San Miranda, 36°26'26"S 146°22'16"E, 17.xi.2019, S. & T. Corbin (DE). 1 ♂, Westerfolds Reserve, Lower Templestowe, 77 m, 8.xii.2013, K. Green, emerging after dusk; 1 ♂, Reserve beside Yarra Rv, Lower Templestowe, 26.xi.2013, K. Green, emerging



Figs 1–4. *Yoyetta robertsonae* **sp. nov.**, adult: (1) male, dorsal view; (2) male, ventral view; (3) female, dorsal view; (4) female, ventral view.

after dusk (LWP). 1 ♂, Starvation Ck, McMahons Creek township, 1.i.2011, S. Smith; 9 ♂♂, (1 gen. prep. YO35), Anakie, 14,16,29.xii.2003, S.K. Smith; 8 ♂♂, 5 ♀♀ (1 ♂ gen. prep. YO44), Warburton, 14,31.xii.2007, 1.i.2011, Stephen Smith; 1 ♂, East Warburton, 14.xii.2007, Stephen Smith; 1 ♂ (gen. prep. YO56), Narbethong, 11.i.1987, A.F. Atkins; 3 ♂♂, 18 km South Broadford, 26.xii.1985, K.L. Dunn; 3 ♂♂, 2 ♀♀, nr Lerderberg State Pk, 15 km N of Bacchus Marsh, 27.xii.1991, Stephen Smith (MSM). 1 ♂, 1 ♀, Warburton, 31.xii.2007, Stephen Smith (MV).

Description. Male (Figs 1–10). *Head* wider than lateral margins of pronotum; mostly black with a dull yellow triangular spot between lateral ocelli based on posterior margin; supra-antennal plates sometimes edged yellow; ocelli light brown; postclypeus black with inner dorsal surface dull yellow or light brown, a partly yellow midline towards anterior and sometimes a narrow dull yellow lateral margin; anteclypeus shiny black; rostrum reaching bases of hind coxae, black with hints of brown basally; antennae black.

Thorax mostly black. Pronotum sometimes with dark brown patches and a central dull yellow fascia not quite full length; pronotal collar black sometimes partially dull yellow or pale brown along posterior margin. Mesonotum black sometimes with hints of brown following parapsidal sutures; cruciform elevation dull yellow to pale brown apart from a broad black midline and mainly black anterior arms; wing grooves black with dull yellow to pale brown outer margin variable in extent. Metanotum black except for dull yellow to pale brown section either side of midline. Thorax below black often with brown anepisternum 2 and epimeral lobes and usually edged reddish brown around mid and hind leg cavities.

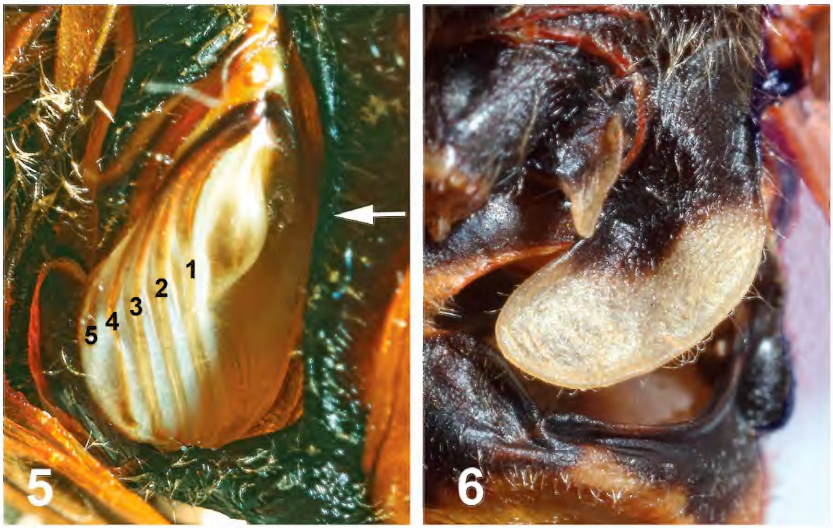
Legs black with dull yellow to pale brown markings, variable between individuals. Coxae tending dull yellow to pale brown distally; fore femora with inner surface black sometimes with hints of dull yellow to pale brown, the outer surface predominantly dull yellow or pale brown to varying degrees but usually black along femoral spines; mid and hind femora dark brown to black except at distal joint; tarsi dull yellow to pale brown suffused black; meracantha black on about basal half, otherwise dull white or occasionally pale brown.

Wings with fusion of forewing veins M and CuA no longer than length of basal cell, rarely barely fused; forewing costal margin orange-brown to almost black, otherwise venation black except for light brown base to vein CuP+1A; basal membrane light brown to bright orange. Hindwing venation black; plaga light brown.

Opercula (Fig. 6) black basally, otherwise dull white to pale brown.

Timbals (Fig. 5) with five long ribs; ribs 1–4 spanning the timbal membrane, fused dorsally on basal spur; rib 5 short, detached from others, occupying dorsal half of timbal only; timbal plate with well developed, elongate dome bearing a distinct point of apodeme attachment near centre.

Abdomen with tergites 1 and 2 black; tergites 3–7 predominantly orange each with a large black mark on dorsal midline, these mostly gradually increasing in size towards posterior but not always reaching anterior margin especially that on tergite 3; each tergite also edged black along posterior margin considerably



Figs 5–6. *Yoyetta robertsonae* **sp. nov.**, male: (5) left timbal with ribs numbered and vestigial timbal cover arrowed; (6) right operculum. (Photos David Rentz.)

variable in extent between individuals; tergite 8 black except for dull orange mark at each lower anterior corner. Sternite I mainly orange; sternite II black except for partly orange posterior margin; sternites III–VII orange except sometimes for small black spot on VII at centre of posterior margin; sternite VIII black basally, thereafter becoming orange-brown.

Genitalia (Figs 9–12) with pygofer upper lobe of moderate size, broad and broadly rounded at apex; basal pygofer lobe small weakly developed, broadly rounded; median lobe of uncus well developed but not excessively long, slightly concave dorsally, in lateral view straight, narrow parallel-sided; claspers robust, claw-like, in ventral view tending parallel-sided, clearly separated; aedeagus recurved distally through 180 degrees, the vesica weakly toothed either side subapically, apex terminating in a very small, slender, transparent 'beak' pointing outwards and a pair of very small flat ear-like lobes pointing inwards minutely toothed; pseudoparameres very long, reaching almost to distal part of theca, transparent, very slender, hair-like and often weakly knobbed apically.

Measurements (in mm; range with mean in parentheses for 10 males and 10 females, including smallest and largest specimens). *Length of body including head*: male 20.9–23.6 (22.6); female 21.3–24.7 (23.0). *Length of forewing*: male 24.6–28.9 (27.0); female 28.1–32.6 (30.3). *Width of forewing*: male 8.5–10.4 (9.5); female 9.9–12.0 (10.7). *Ratio width/length of forewing*: male 2.7–3.0 (2.8); female 2.7–3.0 (2.8). *Width of head (including eyes)*: male 5.8–6.9 (6.4); female 6.6–7.6 (7.1). *Width of pronotum (across lateral angles)*: male 6.2–7.5 (7.0); female 7.2–8.2 (7.8).

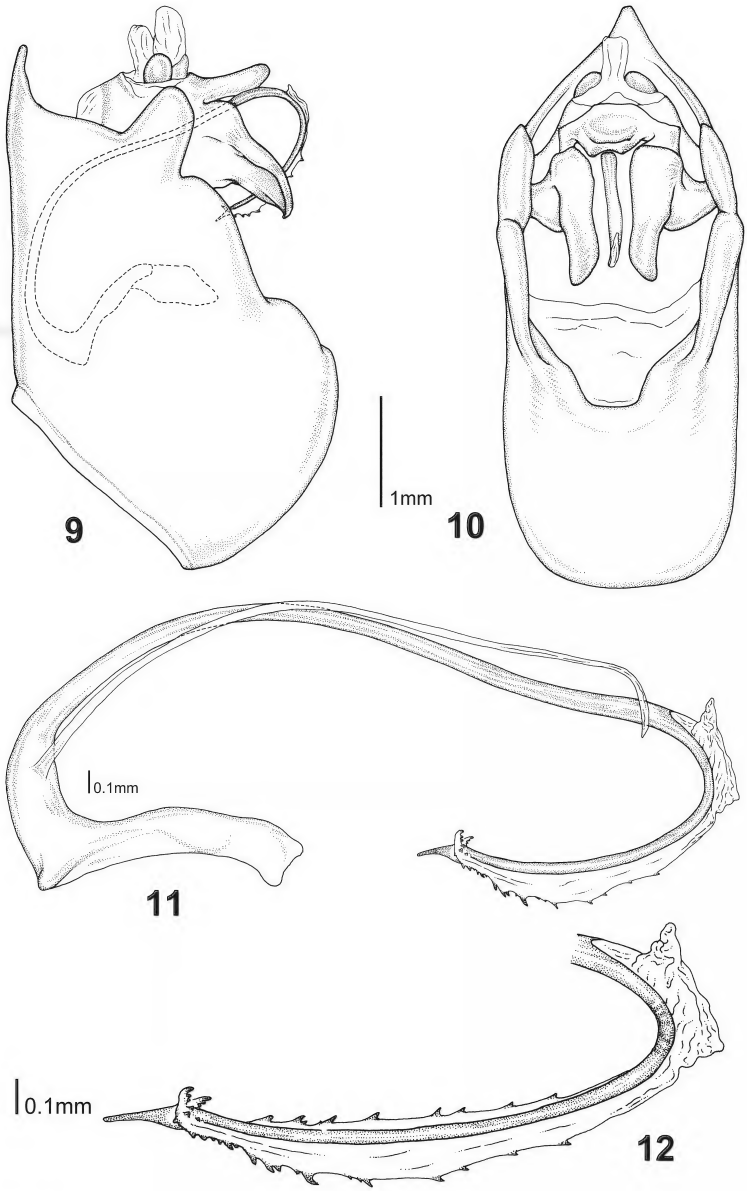
Figs 7–8. *Yoyetta robertsonae* **sp. nov.**, adult: (7) male, live specimen, Canberra; (8) female, live specimen, Wangaratta (Fig. 8 photo, Nathan Emery).

Males from the northern part of the species' range tend on average to be a little larger than those from Victoria.

Distinguishing features

Yoyetta robertsonae is very similar in its general appearance to all other species in the *Y. tristrigata* species group. It is best distinguished from all species except *Y. humphreyae* and some larger males of *Y. repetens* by its larger size, its forewing length being at least 26 mm in males and 28 mm in females.

Males of *Y. robertsonae* can be distinguished from males of *Y. repetens* by the



Figs 9–12. *Yoyetta robertsonae* **sp. nov.**, male genitalia: (9) lateral view; (10) ventral view); (11) aedeagus, lateral view; (12) distal aedeagus showing detailed morphology.

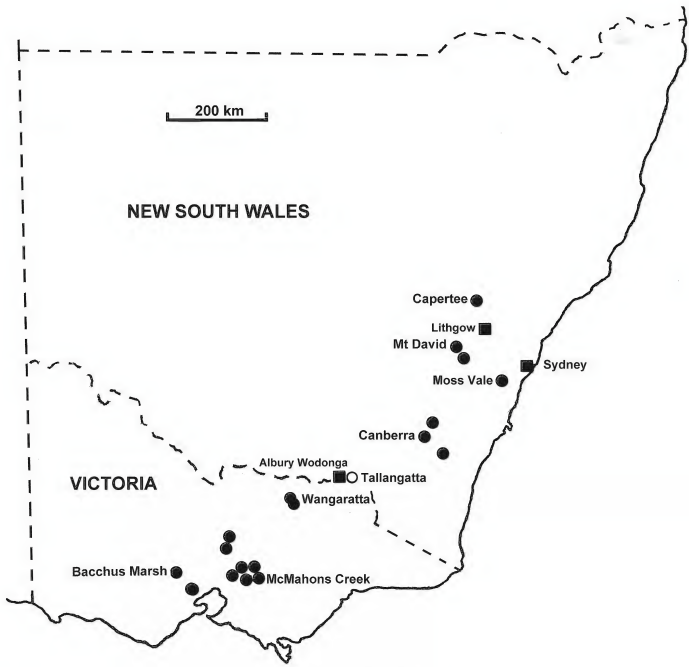


Fig. 13. Distribution of *Yoyetta robertsonae* **sp. nov.** Collection localities are shown as black spots; aural records by circles. Towns without collection records are shown as black squares.

width of timbal rib 5, which in *Y. robertsonae* is similar to that of rib 4, but in *Y. repetens* it is considerably narrower than the widest portion of adjacent long rib 4. Males can only be distinguished confidently from those of *Y. humphreyae* and *Y. repetens* by the genitalia. The claspers of *Y. robertsonae* are more or less parallel but in *Y. humphreyae* and *Y. tristrigata* are widely diverging (usually visible without dissection). There is also a marked difference in the size of the uncus between *Y. robertsonae* and *Y. humphreyae*, that of the latter being exceptionally large, several times longer than wide. Females of *Y. robertsonae* differ from *Y. humphreyae* in having the mesonotum black or almost so whereas in *Y. humphreyae* it is largely brown with black sigilla. Further, the apex of the male theca of *Y. robertsonae* is characteristic with its very short lanceolate apex bearing a pair of upright basal lobes (Figs 11, 12).

Etymology. Named for Susan Robertson whose passion for cicadas led to her collecting some of the original specimens of this new species. Her dedication to observing and collecting cicadas over many years has also contributed towards a better understanding of the cicadas of the Australian Capital Territory.

Distribution and habitat (Fig. 13). The Central and Southern Tablelands of New South Wales, in lower elevations of the Australian Capital Territory, and in Victoria inland of the Great Dividing Range south to outer districts of Melbourne. In New South Wales the species is found at altitude at Mount David near Oberon (~1,000 m) (S. & B. Underwood), but there are also records from much lower elevations along the Western Slopes of the Great Dividing Range in NSW south from Capertee (D. Emery), the ACT and in Victoria. It is sometimes a locally common species in NSW and around Canberra in the ACT. In Victoria, large populations are common (2012, 2016, 2019), especially along watercourses

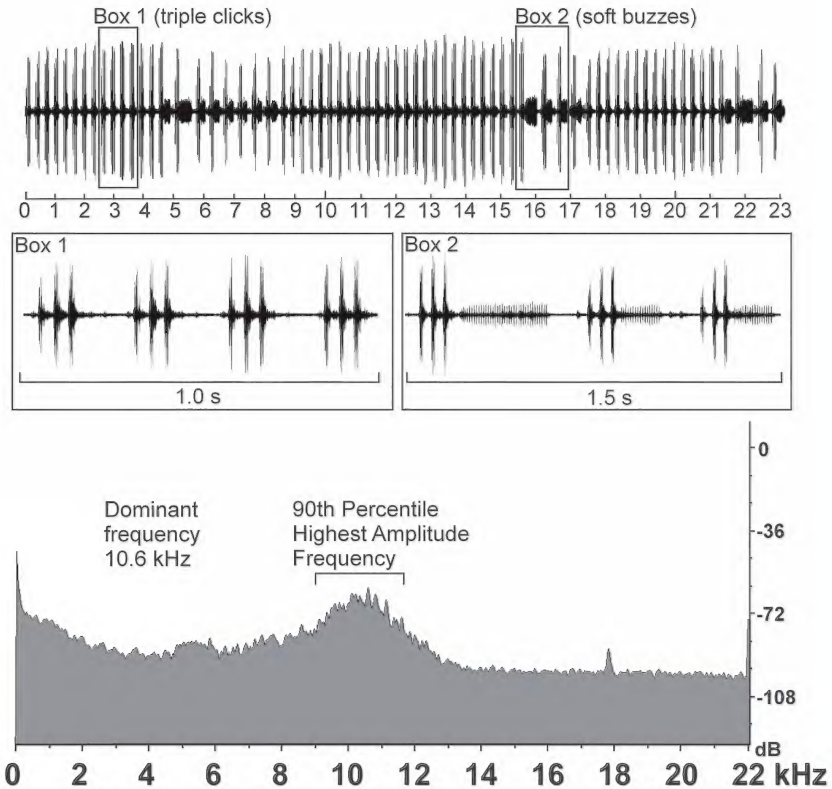


Fig. 14. *Yoyetta robertsonae* **sp. nov.**, male calling song structure in waveplot form. Boxes 1 and 2 are expanded from the top plot to illustrate the detailed structure of the sections containing triple clicks and soft buzzes, respectively. The spectrogram at the bottom of the figure shows song frequency. The specimen was recorded in the field at the base of Black Mountain, Canberra (35°16'S 150°50'E) by LWP using a Tascam DR-07 digital recorder with an Audio-Technica ATR-55 cardioid condenser shotgun microphone (linear frequency response up to 18 kHz).

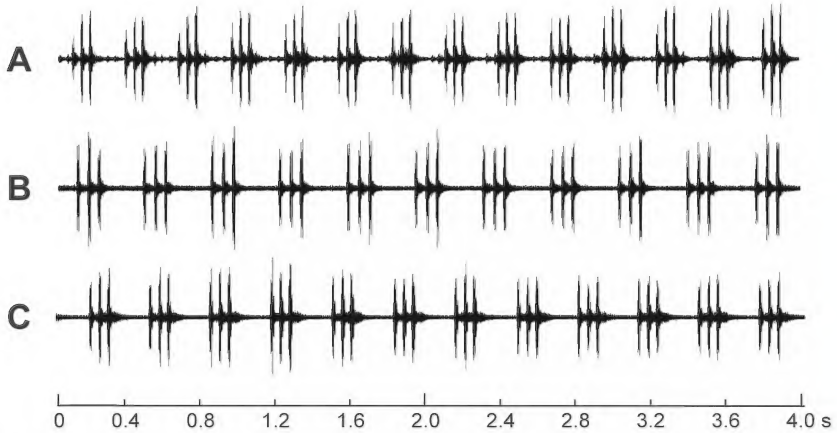


Fig. 15. *Yoyetta robertsonae* **sp. nov.**, waveplots comparing the male calling song structure from three different localities: (i) Black Mountain, Canberra (35°16'S 150°50'E, (ii) Moss Vale (34°33'S 150°22'E), and (iii) Oberon (33°42'S 149°52'E). All recordings were made in the field by LWP (see Fig. 14 caption for recording equipment details).

such as the Yarra, Ovens and Goulburn rivers, where emergences occur during daylight on lower shrubs, grasses and fences. Throughout its range, it prefers open sclerophyll woodlands, where males generally call from the upper branches of eucalypts. Adults have been taken from early November to mid January but most records are for December.

Calling song. *Yoyetta robertsonae* produces a series of evenly spaced triple clicks (see Figs 14, 15). This may continue monotonously, as shown in Figure 15; however, as the song progresses, the triple clicks may be interrupted by soft buzzes (Fig. 14). In detail, the triple clicks each contain a set of three discrete double (or rarely triple) syllables, each 0.01–0.02 s duration and separated by silent gaps of 0.03–0.06 s. Their structure is defined by the long silent gaps of 0.16–0.35 s duration between each triple click, resulting in a repetition rate of 2.0–3.2 triple clicks/s. In the soft buzzing sections (Fig. 14), each triple click is followed by a short gap (0.02–0.12 s duration), a soft buzz of variable duration (0.11–0.52 s) and a long gap (0.07–0.24 s). The longest soft buzz examples typically occur at the beginning of each soft buzzing section.

The calling song has a distinct highest amplitude frequency plateau (Fig. 14), which exhibits no evidence of modulation during song production. Based upon available recordings (n=29), the 90th percentile of sound energy characteristically falls within the range of 9–12 kHz, with a dominant frequency between 10.0 and 11.5 kHz (Fig. 14).

There are consistent amplitude variation patterns evident within the structure of the calling song. The triple click sections are loud, with the initial click in each triple click being the quietest (Figs 14, 15). In the sections with soft buzzes, the

Table 1. Character matrix for the nine described species of the *Yoyetta tristrigata* species group together with *Y. regalis* from the *Y. abdominalis* species group used as outgroup.

Species	12345	67890	11 12
Y. regalis	00000	00000	00
Y. tristrigata	11000	00001	00
Y. humphreyae	11001	11101	00
Y. nigrimontana	11110	01111	00
Y. landsboroughi	11110	00111	00
Y. fluviatilis	11010	00111	00
Y. robertsonae	11000	10111	11
Y. cumberlandi	11000	10111	11
Y. repetens	11000	01111	11
Y. celis	11010	00111	01

buzzes themselves are considerably quieter than the triple clicks that precede them. Indeed, at a distance, the soft buzzes are barely discernible, giving the impression that there are simply extended pauses between the triple-clicks. Observations by LWP confirm that males will actively approach when finger snaps or tongue clicks (simulating female wing flicks) are timed precisely to occur in the silent gaps after each soft buzz. This indicates that the soft buzzes act as close proximity cues to facilitate mate attraction and localisation.

The singing behaviour of *Y. robertsonae, Y. celis, Y. cumberlandi* and *Y. repetens* is similar in that they all call when stationary and may or may not continue to call briefly when moving between singing stations. In this species group, only *Y. tristrigata*, *Y. humphreyae* and *Y. nigrimontana* call predominantly in flight. The soft buzz of *Y. robertsonae* is similar to the 'quiet syllable sequence' produced by *Y. cumberlandi*, as described by Emery *et al.* (2015).

Phylogenetic relationships

Moulds (2005) and Marshall *et al.* (2016) showed that *Yoyetta celis* (Moulds), together with *Y. denisoni* (Distant), was sister to the genus *Birrima* Distant that in turn forms part of a broader clade including *Plerapsalta* Moulds, *Auscala* Moulds and *Marteena* Moulds. However, relationships within *Yoyetta* itself remain largely unknown and molecular date are limited to just COI barcodes for a few species (Ratnasingham and Hebert 2007). Further, the species of *Yoyetta* are remarkably similar morphologically, especially within the *tristrigata* species group where even colour patterns are remarkably similar, so that relationships are not obvious. In an attempt to elucidate relationships for *Y. robertsonae*, we include here a cladistic analysis of the *tristrigata* species group to which *Y. robertsonae* belongs. Data were analysed using the heuristic search parsimony algorithms implemented

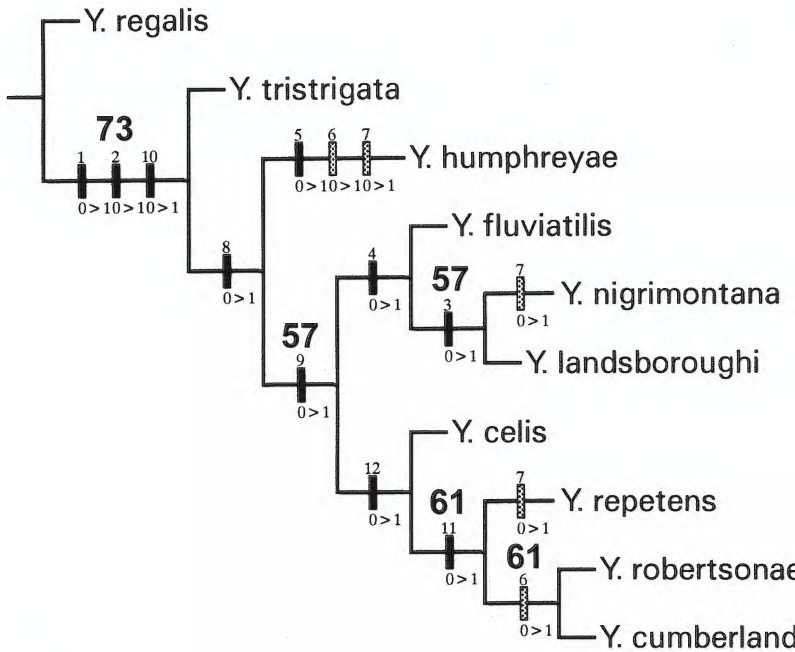


Fig. 16. One of the four most parsimonious trees derived using the procedures described in the text above (length 16, CI 75, RI 88) from an analysis of all species in the *Yoyetta tristrigata* species group, employing *Y. regalis* as outgroup, with all characters unordered and equally weighted. Numbers at nodes are bootstrap values >50% from 1,000 replications. This tree was chosen as its subgroupings matched those in a tree derived from a limited genetic data. Character transformations (generated using Clados) are represented by black bars = non-homoplasious forward changes and grey bars = homoplasious forward changes.

with PAUP* version 4.0b2 (Swofford 1998). Tree searches used the tree bisection reconnection algorithm (TBR) conducting 1,000 random addition searches (RAS) starting from random trees; other settings were left at their default values. All characters were unweighted and all multistate characters were treated as unordered. *Yoyetta regalis* Emery, Emery & Popple, 2019 from the *abdominalis* species group (Emery *et al.* 2015) was chosen as the outgroup. The characters and character states used are listed below and the matrix of species and assigned states are given in Table 1.

Characters and character states

1. Plaga: (0) whitish; (1) brownish.
2. Male abdominal colour: (0) mainly black; (1) mainly orange or yellowish brown.
3. Timbal long rib 4: (0) spanning timbal membrane: (1) not spanning timbal membrane.

4. Timbal long rib 5: (0) not spanning timbal membrane; (1) spanning timbal membrane.
5. Uncus (0) short; (1) exceptionally long.
6. Claspers: (0) strongly diverging; (1) parallel or tending so.
7. Clasper apex: (0) straight; (1) turned outwards.
8. Apex of theca: (0) not lanceolate; (1) lanceolate.
9. Apex of theca: (0) strongly downturned; (1) straight or weakly curved.
10. Vesica: (0) smooth; (1) toothed.
11. Female abdominal segment 9: (0) slender; (1) broad.
12. Distal portion of theca: (0) not turned as much as 180°, often much less; (1) turned through 180°.

Results and discussion

The analysis found four most parsimonious trees, two of which were unresolved in the upper part of the tree, and two of which were fully resolved and differed only in the position of *Y. celis* as sister to either of two upper clades. The groupings in one of these trees (Fig. 16) were mostly in accordance with a maximum likelihood tree generated from the limited barcode sequences available (LWP, unpublished data), and in the absence of other evidence, this tree is considered the most likely reconstruction of true phylogenetic relationships.

Yoyetta tristrigata was found to be sister to all other species of the ingroup in all trees. It differed from them in lacking a lanceolate apex to the theca, instead terminating in a bluntly pointed apex bearing small tubercles, not unlike some species in the outgroup (character 8). *Yoyetta humphreyae* was then sister to the remaining ingroup species separated by its short down-turned lanceolate thecal apex (character 9) but also differing in other attributes (characters 5, 6, 7).

The remaining species fell within two clades, one comprising *Y. fluviatilis, Y. nigrimontana* and *Y. landsboroughi* distinguished by timbal rib 5 spanning the timbal membrane (character 4), the other *Y. celis*, *Y. cumberlandi, Y. repetens* and *Y. robertsonae* distinguished by the distal portion of theca turned through 180° (character 12). *Yoyetta celis* is early branching in the latter, the same as suggested by barcodes. It is unusual among its relatives in the *Y. tristrigata* species group in that adults inhabit tea trees and paperbarks rather than eucalypts (Moulds 1990); although *Y. tristrigata* sometimes also inhabits paperbarks at Mount Molloy (DE), and *Y. landsboroughi* can sometimes be found in tea trees in western Sydney (Moulds 1990).

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A NEW SPECIES OF *FRAUS* WALKER, 1856 (LEPIDOPTERA: HEPIALIDAE) FROM THE SOUTH-WEST OF WESTERN AUSTRALIA

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Abstract

The species *Fraus extremapodus* **sp. n.** from Western Australia is described, illustrated and compared with the sympatric *F. basidispina* Nielsen and Kristensen, 1989 and *F. polyspila* (Meyrick, 1890). With a wingspan of 39 mm it is one of the largest species of *Fraus* Walker, 1856 and, compared to wing length, it has the longest legs of any Australian hepialid.

Key words: taxonomy, homoneurous, short-range endemic, mesic zone

Introduction

Fraus Walker, 1856 is a diverse, endemic genus of primitive ghost moths with 25 species found across much of southern and eastern Australia. They are among the smallest of the Hepialidae, and certainly the smallest in Australia with a wingspan between 15 and 35 mm. Like many genera in this family, *Fraus* are often confined to areas of higher rainfall, though a few species are known from drier semi-arid environments such as mallee or dry heathland particularly in South Australia and Western Australia.

Fraus are generally considered Hepialidae *s. lat.* or 'primitive' Hepialidae due to the presence of a proboscis vestige in some species, the lack of pseudoempodial setae on the pretarsus, less connection between the trulleum and juxta, and an unbroken ventral row of spines on segment VII of the pupa (Nielsen and Scoble 1986; Nielsen and Kristensen 1989). *Fraus* was removed from Hepialidae *s. str.* by Nielsen and Scoble (1986) along with the similar genera *Gazoryctra* Hübner, *Antihepialus* Janse and *Afrotheora* Nielsen and Scoble, a determination followed by Grehan (2012) and Simonsen and Kristensen (2017), who found that those latter genera together form a monophyletic clade, however were unable to resolve the relationship between that clade, *Fraus*, and the Hepialidae *s. str.* Nielsen and Kristensen (1989) postulated that the monophyly of Hepialidae *s. str.* could not be supported without retention of *Fraus* as Hepialidae *s. lat.* Reiger *et al.* 2015 found evidence in the form of a molecular phylogenetic analysis of the basal lineages of Lepidoptera which supported the monophyly of Hepialidae *s. lat.* only for *Gazoryctra*. Further work is required to determine if the 'primitive' hepialid genera warrant subfamilial status (J. Grehan pers. comm.).

Fraus are easily distinguished from other comparably small Australian Hepialidae such as *Jeana* Tindale by comparison of wing venation. In *Fraus*, Rs_1 shares a stalk with Rs_2, and Rs_3 + Rs_4 also share a common stalk in both wings compared with *Jeana* which has typical 'oxycanine' venation (Meyrick, 1890; Dumbleton, 1966), where Rs_3 branches off Rs_1 + Rs_2, as well as major differences in male valvae, which though simple parallel-sided in *Jeana,* are often elaborate or club-shaped in *Fraus*, and with the retention of the proboscis in some species of the latter, which *Jeana* lack. *Oncopera* Walker, though of a comparable size, are

of much heavier build and, except for *O. brachyphylla* Turner, have elaborate metatibial androconia in the males, which *Fraus* lack. All *Fraus* share the combined features of: elongate elliptical scales with flattened or serrate apexes, and the females with a patch of hair-scales at the hindwing basal area.

A succinct account of the short taxonomic history of *Fraus* is recorded by Nielsen and Kristensen (1989), who added 17 new species to the existing eight in their landmark revision, and recognised two synonyms. *Fraus extremapodus* **sp. n.** is the first new *Fraus* species to be described since Nielsen and Kristensen (1989), bringing the total number of recognised species to 26.

Methods

Material examined for this study for morphological comparison other than that which is listed within the systematic component: *F. pelagia* (Turner): 1 ♂, lectotype, 1 ♀ paralectotype (in ANIC); *F. simulans* (Walker): 105 specimens: 63 ♀, 33 ♂ (in SAMA), 7 ♂, 2 ♀ (in EPBC). *F. basidispina* Nielsen and Kristensen: 8 paratypes: 2 ♂, 6 ♀, non-types: 1 ♀, 1 ♂, (all in SAMA). *F. pteromela* (Lower): 1 ♂ lectotype, 1 ♀ paralectotype, non-types: 43 ♂ 38 ♀ (in SAMA), 11 ♂, 5 ♀ (in EPBC). *F. polyspila* (Meyrick): 119 ♂, 33 ♀, (in SAMA), 10 ♂, 4 ♀ (in EPBC). *F. quadrangula* Nielsen and Kristensen: 10 ♂, 1 ♀ paratypes, non types: 2 ♂, 5 ♀ (in SAMA).

Other material examined primarily for comparison of wing scale structure and/or leg ratios (see discussion), all in SAMA: *Gorgopis libania* (Stoll): 3 ♂ 1 ♀. *Eudalaca stictigrapha* (Hampson): 2 ♂ paratypes. *Gazoryctra wielgusi* Wagner and Tindale: paratypes: 11 ♂. *Jeana delicatula* Tindale: 1 ♂ holotype, 1 ♀ paratype, 1 ♂ paratype. non-types: 4 ♂, 9 ♀. *Abantiades argentata* (Tindale): 1 ♂ holotype, 1 ♀ paratype. *Aenetus lewinii* (Walker): 3 ♂. *Oncopera intricata* Walker: 1 ♂. *Elhamma australasiae* (Walker): 1 ♂. *Oxycanus australis* Walker: 1 ♂. *Zelotypia stacyi* Scott: 1 ♂. Anomosetidae: *Anomoses hylecoetes* 1 ♂ . Prototheoridae: *Prototheora petrosema*: 1 ♂.

Dissection: Genitalia: The abdomen was removed and placed in 20% KOH solution and heated over a flame for 6–8 minutes before being cleaned with distilled water, then stored in ethanol in a labelled vial kept in a tray adjacent to the pinned specimen in SAMA. Legs: the legs in Figs 12–17 were removed from the set specimens and placed in 20% KOH solution for 15 minutes at ambient room temperature, then were cleared of scales using a fine brush and are stored in a separate vial in the same manner as the genitalia. Genitalia were compared directly to both other dissections and with set specimens, and also with those figured in Nielsen and Kristensen (1989: 176–185, Figs 306–363), which, although slide mounted, still allow for appropriate morphological comparison with the non-slide mounted dissections performed for this study.

Dissections were imaged in an alcohol solution using a Leica imaging system composing a Leica binocular microscope, Leica DFC 500 camera and the LAS Core software programme. Whole specimen images were taken using a Canon EOS camera, with a Canon EF 100 mm 1:2.8 Macro lens and Canon Speedlite Transmitter and Speedlite 430 EX11 flashes. The images were then stacked using the Zerene stacker software programme.

Diagrams of adult wing venation were drawn freehand by tracing images of the

wings, the resulting drawings were then compared with the set specimens to ensure accuracy. Terminology for genitalia and wing morphology follows Nielsen and Kristensen (1989), and Simonsen (2018). Informal species-groups referred to in the text follow Nielsen and Kristensen (1989).

Fig. 1. Male *Fraus extremapodus* **sp. n.**, holotype.

Figs 2–3. Male *Fraus* spp: (2) *F. polyspila*; (3) *F. basidispina,* paratype.

Abbreviations: General: SAMA—South Australian Museum, Adelaide. ANIC—Australian National Insect Collection, Canberra. WAM—Western Australian Museum, Perth. KGC—research collection of Kees Green, Melbourne. EPBC—research collection of E.P. Beaver, Adelaide.

Morphology: FW—forewing. HW—hindwing. For male genitalia (Figs 3–11): br—basal rim of pseudotegumen. ip—intermediate plate. jx—juxta. pa—pseudoteguminal arm. pst—pseudotegumen. sac—saccus. scc—sacculus. s8—eighth sternite. tl—tergal lobe. tp—twin processes. tr—trulleum. vi—apodemal vinculum. vl—valvae. For legs (Figs 12–17): fm—femur. ta—tarsi. ti—tibia.

Systematics

Hepialidae Stevens, 1829, *s. lat.*, *sensu* Nielsen and Kristensen 1989

Fraus extremapodus sp. n.

(Figs 1, 4–8, 13–15, 19–21)

Material examined. Holotype ♂, WESTERN AUSTRALIA: Walpole, 34°58'35.4"S 116°42'38.9"E, 22 April 2017, M.D. Moore / specimen no. 17083, H025, dissection no. EPB-05 (in WAM).

Paratypes: 1 ♂: same data as holotype except specimen no. 17084, H026, (in SAMA). 2 ♂: Keystone SF, Walpole, WA, S34.57.58°, E116.41.12°, 50 m elev., 22–28 April 2017, Kees Green (in KGC). 1 ♂: nr Albany, Western Australia, 34.52.427°S, 117.49.984°E, 1–2 May 2000, M. Court. ex. Light trap, *Eucalyptus globulus* plantation #4, 1 / BOLD id 10ANIC-09640 / ANIC Database No. 31 036927 (in ANIC).

Diagnosis. *Fraus extremapodus* is distinctive and not easily confused with any other species. It is distinguished from the males of all other *Fraus* species by the following external characteristics: antennae filiform; absence of wing patterns; extremely long legs, midleg almost the length of the forewing; wing venation distinctive, Sc in FW divided, CuP to margin, 2A present in HW; scales at wing margin dentate. There are distinctive differences in male genitalia, such as the presence of piliform scales on the valvae, although otherwise they bare general similarities to the Western Australian *F. basidispina*, *F. polyspila,* and the Tasmanian *F. pelagia* (see Discussion).

Description. Male. Head: Antennae 8 mm, to middle of costa, slender, filiform, pale brown, scape sub-rectangular, pedicel depressed ovoid, 33 or 34 flagellomeres. Eyes moderate, smaller than head capsule, widely spaced dorsally. Scales on frons and vertex dense and grey. Labial palps two segmented, posterior palpomere short, ovoid, anterior palpomere elongate, narrow. Proboscis absent. Thorax: pro- and mesothorax dorsally and ventrally covered in light grey scales and interspersed with brown scales on ventral surface. Legs very long, all subequal (typical for *Fraus*), (Figs 13–15) prothoracic leg 16 mm, mesothoracic leg 17 mm, metathoracic leg 14.5 mm, all with short grey scales on femur, tibia and tarsus, epiphysis absent, tibia dorsally convex medially in pro and midleg, concave in metaleg. Wings: FW: length 18.5 mm, expanse 39 mm. Narrow, elongate and

subtriangular. Costa straight. Apex rounded. Wing venation (Fig. 21) Sc divided, CuP to margin, 2A absent, otherwise typical for *Fraus.* HW: Narrow, elongate, subtriangular. Costa slightly concave centrally. Tornus rounded. Wing venation (Fig. 21): Sc not divided, 2A present. Wings finely scaled, semi-translucent. Dorsal FW ground colour light grey, without pattern. Scales along costa and basal area slightly darker. Fringe with elongate dark grey scales from apex to jugum, longest at jugum, scales serrate, apex with 6–9 teeth. Jugum long. Patch of long black scales between jugum and thorax. Ventral surface with piliform scales basally. HW dorsal surface light grey, darker along costa. Fringe as for FW. Ventral surface as above. Basal area covered with white piliform scales. Abdomen: long, narrow, uniformly dark grey interspersed with brown scales. Tergum 1 sub-rectangular, length/width ratio 0.89, posterior margin with central indentation. Sternum 8 (Fig. 5) sub-trapezoidal, posterior margin with deep central indentation, anterior margin rounded, sclerotised at posterior corners, less sclerotised medially and anteriorly.

Male genitalia (Figs 4; 6–8). Apodemal vinculum broad and short, with paired posterior projections rounded and smooth. Saccus subtriangular, confluent with apodemal vinculum. Intermediate plate highly sclerotised, roughly triangular with anterior apex pointed. Basal rim of pseudotegumen broad, rounded, posterior margin of pseudotegumen simple, sclerotised, smooth. Ventral pseudoteguminal arm membranous. Twin processes very short, rounded. Juxta broad and rectangular, slightly membranous towards trulleum. Trulleum elongate, highly sclerotised, positioned inferior to pseudotegumen, hook-like projection extending between valvae towards saccus. Valvae large, straight, posterior margin slightly concave, large triangular sclerotised projection at sacculus. Posterior margin clothed with long setae, anterior margin with both setae and piliform scales.

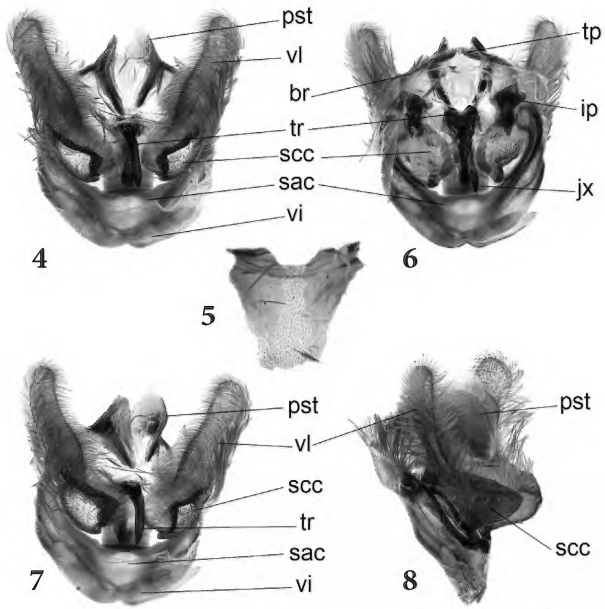
Female Unknown.

Etymology. The species is named in reference to its extremely long legs, longest for any *Fraus* spp. both by actual and proportional length. A suggested common name is ‘Long-legged primitive ghost moth’.

Phenology. Flight time is recorded from the 22 April until 2 May, during or on the same night as rainfall. The species is apparently localised, uncommon to light, and is rarely collected. Some *Fraus* species such as *F. polyspila* (Meyrick, 1890) or *F. pteromela* (Lower, 1892) can occur at light in huge numbers, however *F. extremapodus* has so far only been encountered singularly or in pairs.

Distribution. Specimens are known only from the high rainfall region of south-western Western Australia, where it has been taken from Walpole and near Albany (Figs 22, 23).

Biology. The adults are nocturnal and have been taken at MV and UV light at night, during rainfall. This species occurs in tall mixed *Eucalyptus diversicolor* and *E. jacksonii* woodland and in *E. marginata* woodland, in a thick band of remnant roadside vegetation near a cleared area, while the specimen from near Albany was taken from a *Eucalyptus globulus* plantation. Little is known of the



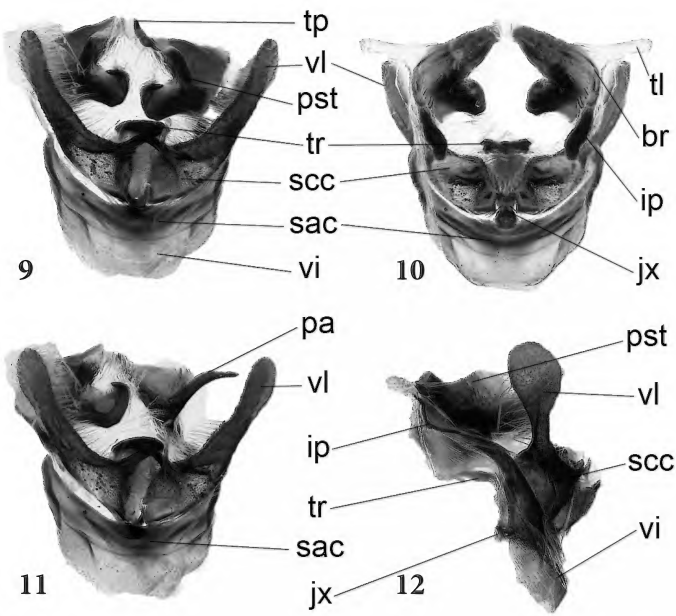
Figs 4–8. Male genitalia and sternite 8 of *Fraus extremapodus* **sp. n.** holotype male, dissection ID EPB-05: (4) posteroventral view; (5) sternite 8; (6) posterodorsal view; (7) ventral 3-quarter view; (8) lateral view. For abbreviations see 'Methods' section.

biology of most *Fraus* species, however one species *F. simulans* Walker, 1856 is univoltine with concealed larvae that are nocturnal grass foliage feeders of both native and exotic species (Hardy, 1973). Further study is required to corroborate the life history of the other *Fraus* spp., including that of *F. extremapodus*.

Discussion

Various aspects of adult morphology are unique to this species, and warrant discussion and comment in comparison with other species.

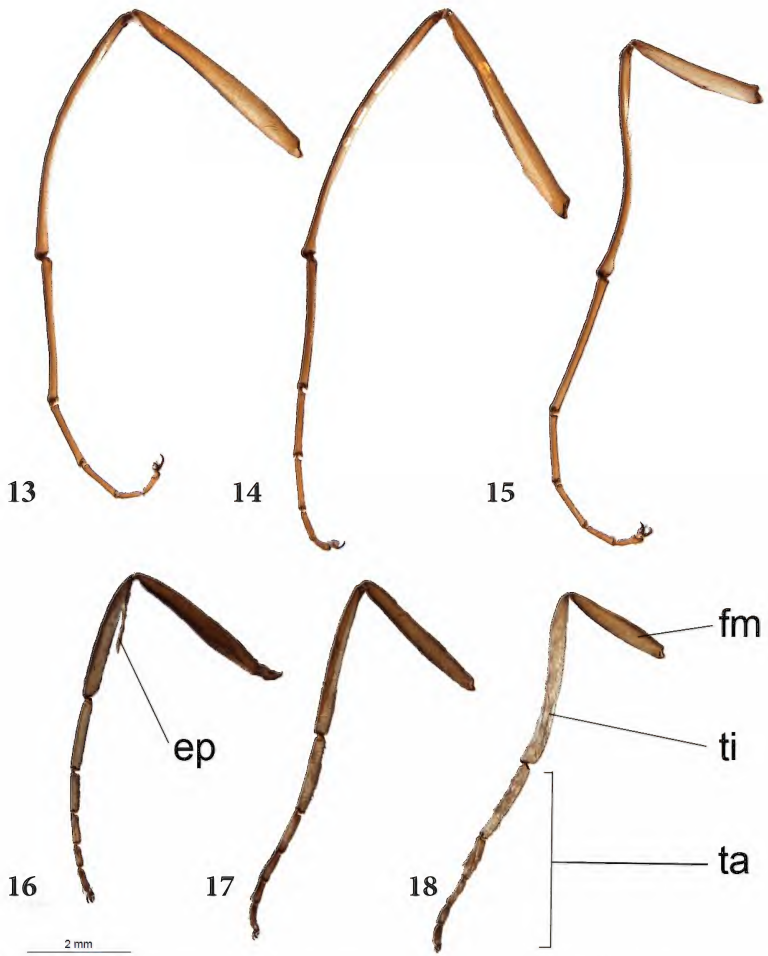
Regarding male genitalia structure, *F. basidispina* (Figs 3, 9–12) have similarly long valvae to *F. extremapodus*, however are distinguished by the presence of two to three short spines on the sacculus; the short, ovoid trulleum; vinculum without posterior projections; pseudotegumen with elongate, spine-like pseudoteguminal arm, twin process longer, narrower; intermediate plate uniformly narrower with apex rounded, not pointed. The male *F. polyspila* (Fig. 2) (for genitalia of *F. polyspila* see Nielsen and Kristensen 1989: 184, 185, Figs 356–359) are similar in the broad sense by way of the trulleum and vinculum shape however the valvae are considerably broader, without anterior triangular structure; pseudotegumen with large centero-ventral spine and prominent ventral arm, which *F. extremapodus* lacks. The male genitalia of *F. pelagia* (see Nielsen and Kristensen 1989: 185, Figs 362, 363) is similar by way of general pseudotegumen and trulleum shape,



Figs 9–12. Male genitalia of *Fraus basidispina* male, dissection ID EPB-02: (9) posteroventral view; (10) posterodorsal view; (11) 3-quarter view; (12) lateral view. For abbreviations see 'Methods' section. Note that sternite 8 could not be located for comparison.

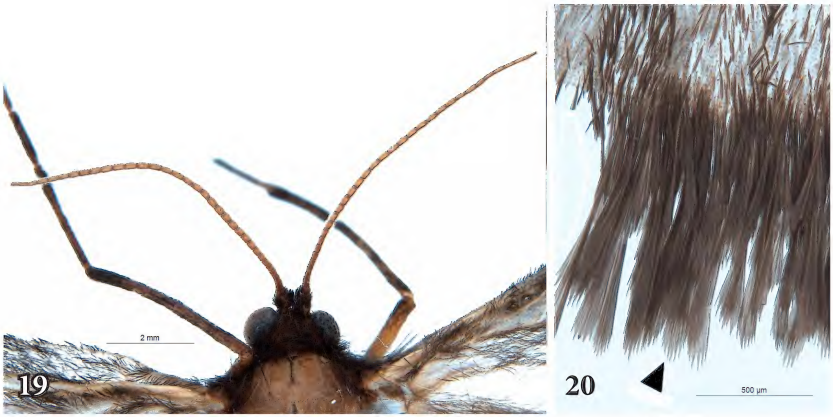
however differ in that the valvae are distinctly club-shaped, pseudoteguminal arms prominent and spine-like, and the vinculum narrow. Despite the superficial similarities in some aspects of male genitalia, *F. basidispina, F. polyspila,* and *F. pelagia* are all distinguished by way of the external characteristics previously listed, and *F. basidispina* with the addition of the presence of a proboscis in that species, which is absent in *F. extremapodus*. A further characteristic of note is that tergum 1 is very similar in shape to *F. quadrangula,* also a Western Australian species, though there is a slightly higher length/width ratio in *F. quadrangula* (0.93) whereas it is 0.89 in *F. extremapodus*, the two species are otherwise dissimilar in many respects, particularly by way of male genitalia, where *F. quadrangula* has distinctively short valvae and a globose trulleum (see Nielsen and Kristensen 1989: 177, 178, Figs 316–319).

There are at least three scale types on the wings of *F. extremapodus*, the most common type is the '*simulans'* type illustrated in Nielsen and Kristensen (1989: Fig. 70 for *F. pelagia*) where the scales are long, slender and with an acute apex, however some of the wing scales are the more typical *Fraus* type where they are elongate with apical margin almost straight with only minute dentation, characteristic of *Fraus* spp. A third scale type that has not been previously recorded



Figs 13–18. Legs of Fraus spp, (13–15): *Fraus extremapodus* **sp. n.**; (13) prothoracic leg; (14) mesothoracic leg; (15) metathoracic leg. (16–18) *Fraus basidispina* (16) prothoracic leg; (17) mesothoracic leg; (18) metathoracic leg. For abbreviations see 'Methods' section. Scale bar applies to all figs.

in other *Fraus* spp. but is present in *F. extremapodus* is best described as an extreme condition of the typical *Fraus* type, where the apical dentations are elongate (Fig. 10), this scale type is confined to the fringe of both fore and hindwings of the new species. This third type is present at the wing fringe in other Hepialidae *s. lat.* such as *Gazorycta* and in Hepialidae *s. str.* such as *Gorgopis* and *Eudalaca* as well as in *Anomoeses* (Anomosetidae) and *Prototheora* (Prototheoridae). This was also recorded by Nielsen and Kristensen (1989) who noted that wing-scale



Figs 19–20. Close-up of key characteristics of male *F. extremapodus* **sp. n.**; (19) filiform antennae; (20) Scales at the margin of the forewing, note the dentate apex (black arrow).

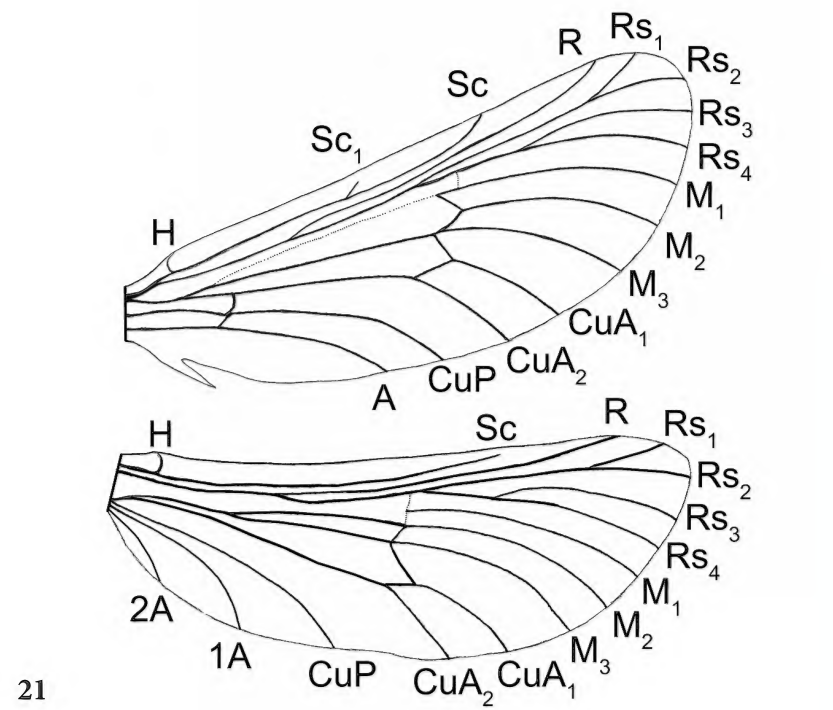


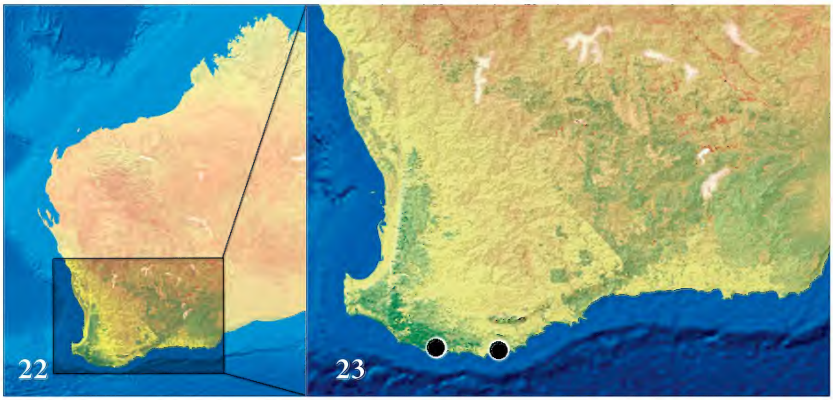
Fig. 21. Wing venation diagram of male *Fraus extremapodus* **sp. n.**

apical margins of Hepialidae *s. str.* are similar, as is that of *Antihepialus,* while the same scale apex type was recorded in *Afrotheora* by Nielsen and Scoble (1986) and by Simonsen and Kristensen (2017) for *Paratheora* Kristensen & Simonsen, *Palaeoses* Turner, and *Genustes* Issiki & Stringer. Another common scale shape in Hepialidae *s. str.* is short, ovoid scales which are present in *Abantiades* and *Aenetus* while *Jeana* interestingly have slender scales with an acute apex of the same shape as the *F. simulans* group (see methods for all material examined). The presence of the prominently dentate scale margins within *F. extremapodus* and in several other unrelated genera is likely plesiomorphic. Details of wing scale structure such as presence/absence of microtrichia could not be observed with the available equipment, however may be of additional future research interest.

Sexual dimorphism is present in *Fraus* spp., with the females larger and usually lighter marked or coloured compared with the males. If this pattern of dimorphism is similar in *F. extremapodus* then the female may be larger than *F. basidispina,* which with a wingspan of 43 mm is currently recognised as the largest *Fraus* species. Additionally, all known female *Fraus* have a patch of hair-scales present (often weakly) at the base of the hindwing, a character unique to *Fraus,* however further collecting is required to discover the female of *F. extremapodus* and check if this feature is present.

Unusually, the wing venation of *F. extremapodus* is different to that of other *Fraus* spp., which are otherwise mostly consistent in terms of wing vein number (Nielsen and Kristensen 1989: Figs 60–62). In the forewing, CuP continues to the wing margin in *F. extremapodus* whereas it ends in the basal area in other *Fraus* species. Additionally, this new species has two anal veins in the hindwing, whereas other *Fraus* species only have a single anal vein. Some *Fraus* species such as *F. nanus* have 2A greatly reduced in the forewing, while others lack it entirely (Nielsen and Kristensen 1989: Figs 61, 62), this new species belongs to the latter group. Vein Sc in the forewing is very finely stalked and S_1 does not extend to the wing margin. Although other *Fraus* spp. do not have Sc divided, other genera are known to have species with both typical and divided conditions such as *Endoclita* Felder (Zhu *et al.* 2004).

Male *Fraus* generally have bipectinate antennae with long, narrow rami except for the Western Australian *F. pilosa*, which can be loosely termed 'unipectinate' in that it only has a single, broadly rounded lobe circumscribing the antennal flagellomeres. *Fraus extremapodus* is further unique within *Fraus* as the antennae lack rami. However, it is not unusual within Hepialidae for extreme infrageneric variation to exist in male antennae structure. *Abantiades* Herrich-Schäffer for example has species with short, singular rami such as *A. aphenges* (Turner), bipectinate species such as *A. mysteriella* Simonsen, and several species with complex, tri-forked rami such as in *A. atripalpis* (Walker) (see Simonsen, 2018 for further comparisons). There is also great infrageneric variation in antennae structure within the large genus *Oxycanus* Walker, with species with bipectinate (*O. silvanus* Tindale) to quadripectinate (*O. byrsa* (Pfitzner)) structure, though this may be problematic as the monophyly of *Oxycanus* is yet to be tested (Beaver *et al.* 2020). Nielsen and Kristensen (1989) list *Dalaca* Walker and *Callipielus*



Figs 22–23. (22) Map of Western Australia; (23) close-up of the south-western corner with the distribution records of *Fraus extremapodus* **sp. n.**

Butler as genera with species that exhibit both filiform and bipectinate conditions, and noted that other genera with the dual condition were known to them.

The legs are noteworthy, when compared to forewing length this species has the longest legs of any Australian hepialid. By comparing the midleg, which is usually the longest leg, and the forewing, the males of other *Fraus* species generally have a leg-to-wing ratio of 0.62–0.80. For example: *F. simulans*: 0.72, *F. pteromela*: 0.67, *F. polyspila*: 0.80, *F. basidispina*: 0.62, while in *F. extremapodus* it is 0.91. For comparison of other Australian Hepialidae *s. str.* genera: *Abantiades argentata*: 0.53, *Aenetus lewinii*: 0.68, *Zelotypia stacyi* 0.35, *Oncopera intricata*: 0.58, *Jeana delicatula*: 0.66, *Elhamma australasiae:* 0.55, *Oxycanus australis:* 0.50. *Archaeoaenetus* Simonsen could not be examined but is expected to be similar to that of *Aenetus.*

The lack of a distinct (by hepialoid standards) proboscis vestige suggests that *F. extremapodus* may be close to the *simulans* group of species, which is the only species group of *Fraus* to lack the proboscis. As previously noted, *F. extremapodus* is similar to *F. basidispina* in the *biloba* group mainly by way of male genitalia where both species appear closer to each other (regarding valvae and general pseudotegumen shape) than to *F. biloba,* however that species and *F. basidispina* are both bipectinate and have a developed tibial epiphysis. The absence of a distinct proboscis vestige, shortened apical palpomere, and the absence of an epiphysis on the foretibia of *F. extremapodus* would suggest this species is close to or within the *simulans s. str.* group *sensu* Nielsen and Kristensen (1989), however the differences in wing scale structure, antennae, and wing venation presents a serious difficulty with assigning this species to any of the informal species groups suggested in that publication and as such this new species is excluded from such grouping.

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This common eastern Australian mantid, *Sphodropoda tristis*, was described in 1871 by Henri Louis Frédéric de Saussure, an early Swiss worker on orthopteroids and wasps. Its Latin species name means 'sad'. Adults reach 63 mm and are greyish brown with fine patterning. When ready to deposit her ootheca, the female excavates a hole in soft soil with her strong, toothed forelegs. She backs into the hole, deposits the ootheca, then refills it using mid and hind legs. This was first observed by Brisbane school teacher, Roly Chapman, in 1981 and was published in this journal in 1984 (Vol **11:** 5–7). Illustration is pen/ink stippling on paper by 2020 ESQ President, Mark Schutze, who is in charge of the DAF insect collection at Ecosciences Precinct in Brisbane. More of his work can be seen at exoskeletonprints.com/prints.html

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